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ENGINEERING STUDIES

PART I

AMERICAN STONE ARCHES

By CHARLES EVAN FOWLER, M. Am. Soc. C. E.

❀

"Whoever thinks a Faultless piece to see,
Thinks what ne'er was, nor is, nor e'er shall be."
* * * * * * * * *
"Content if hence th' unlearn'd their wants may view,
The learn'd reflect on what before they knew."
—*Pope.*

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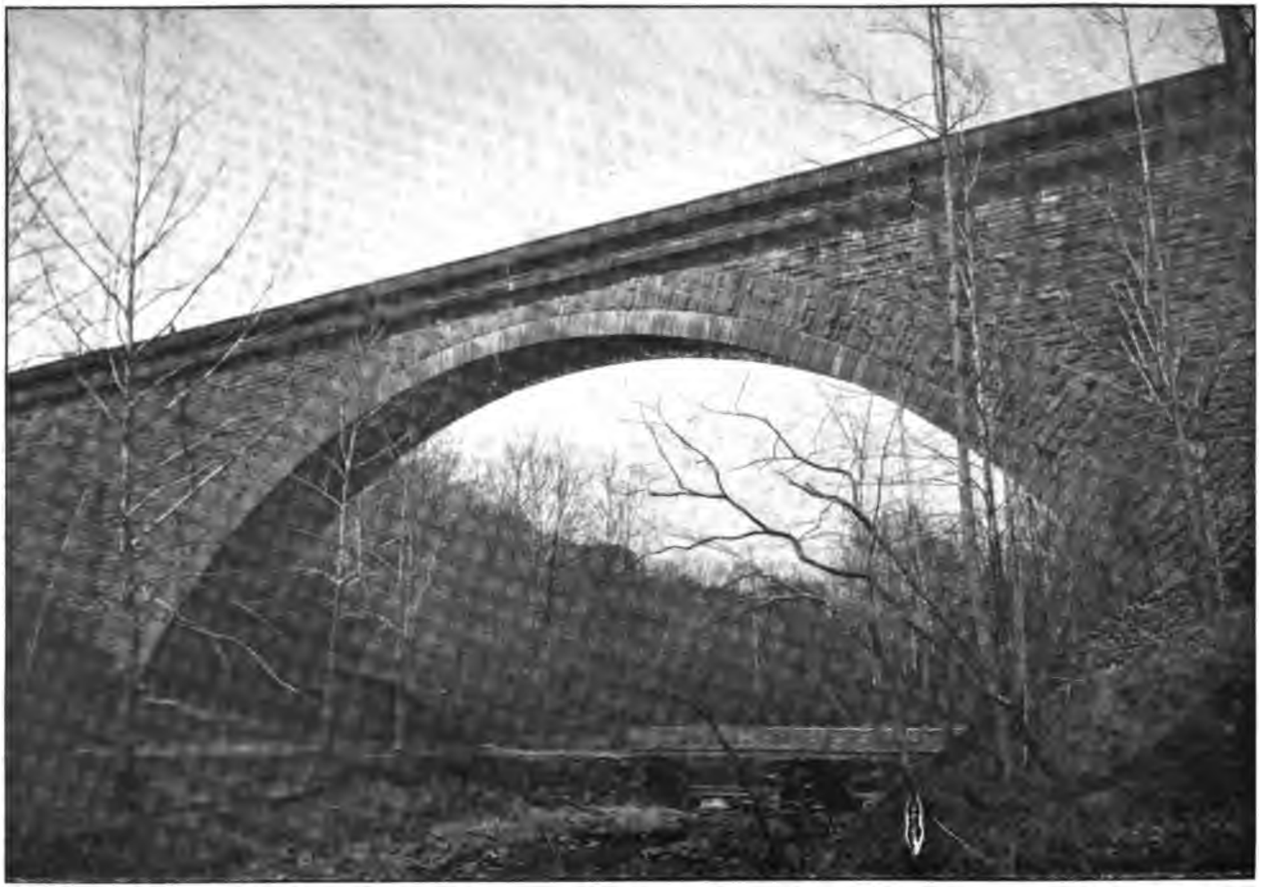
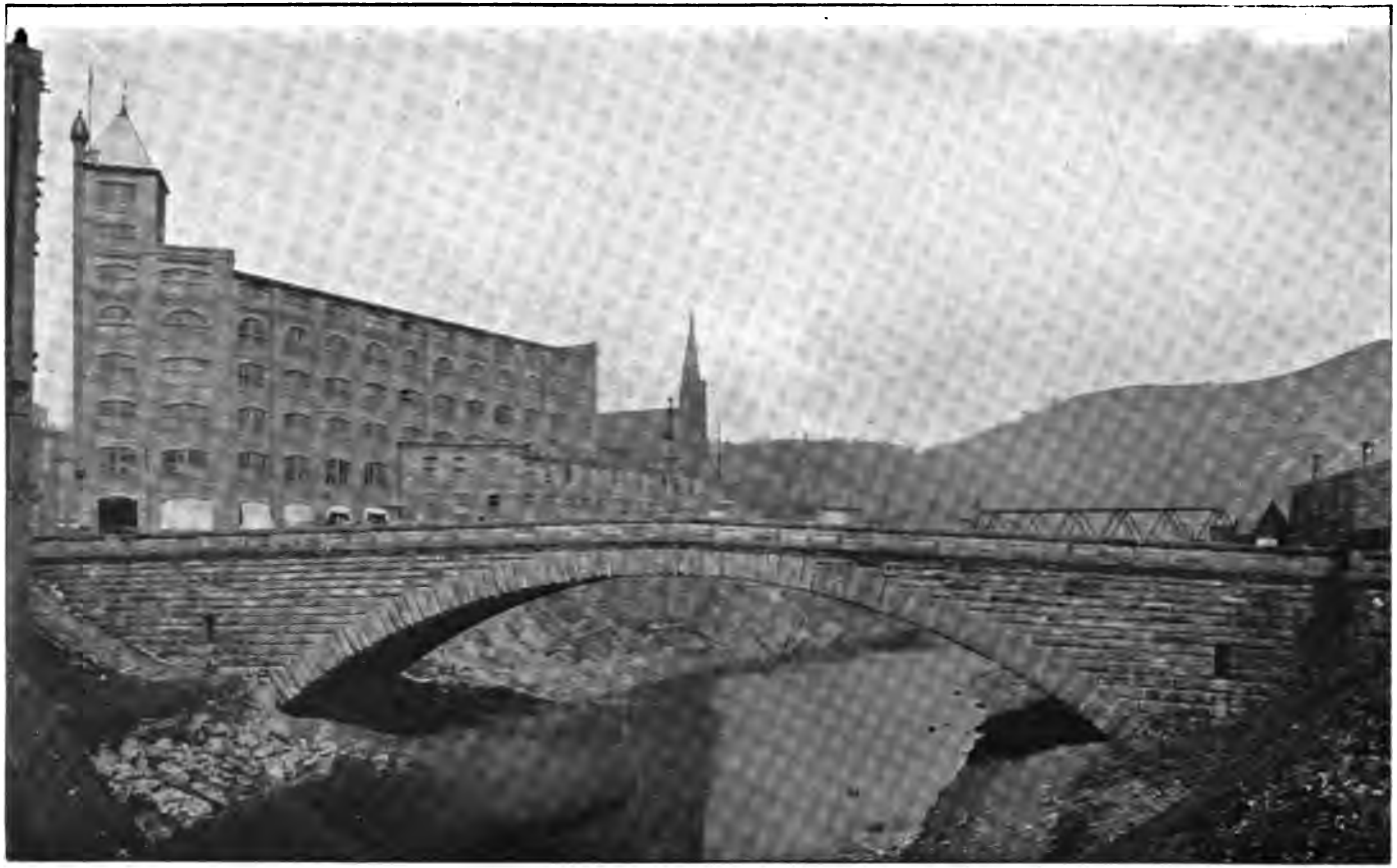
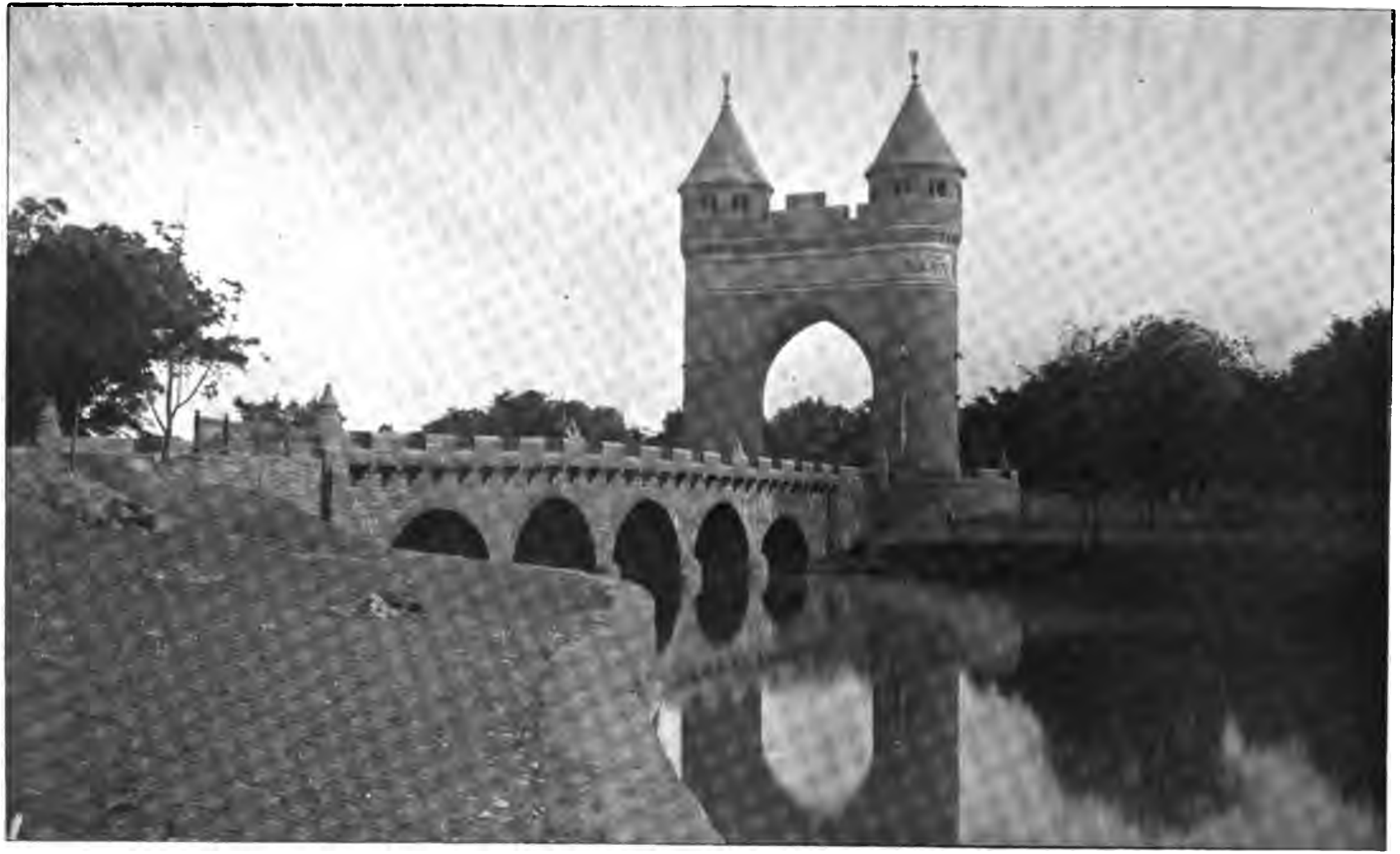


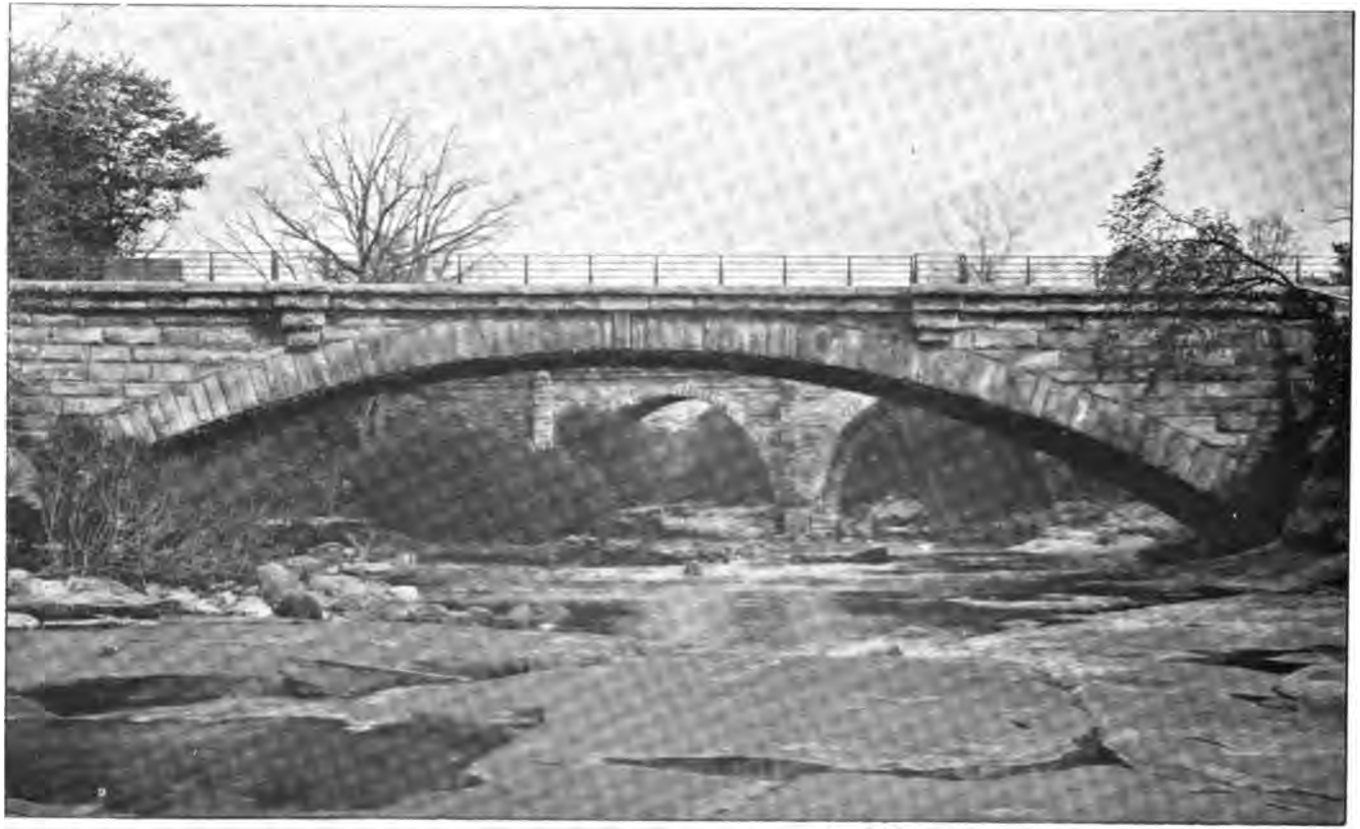
THE CABIN JOHN BRIDGE AND AQUEDUCT, NEAR WASHINGTON, D. C.



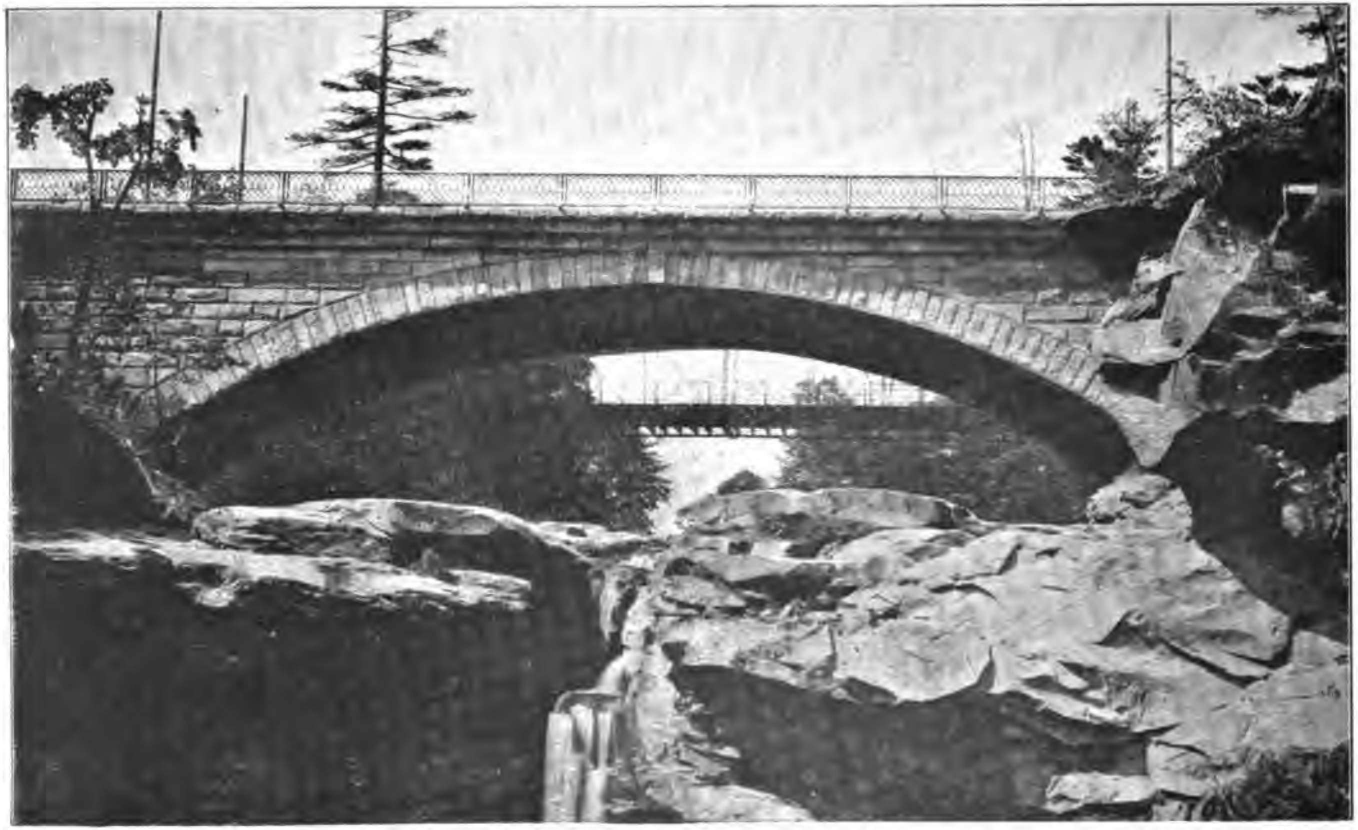
THE WHEELING, W. VA., STONE ARCH.



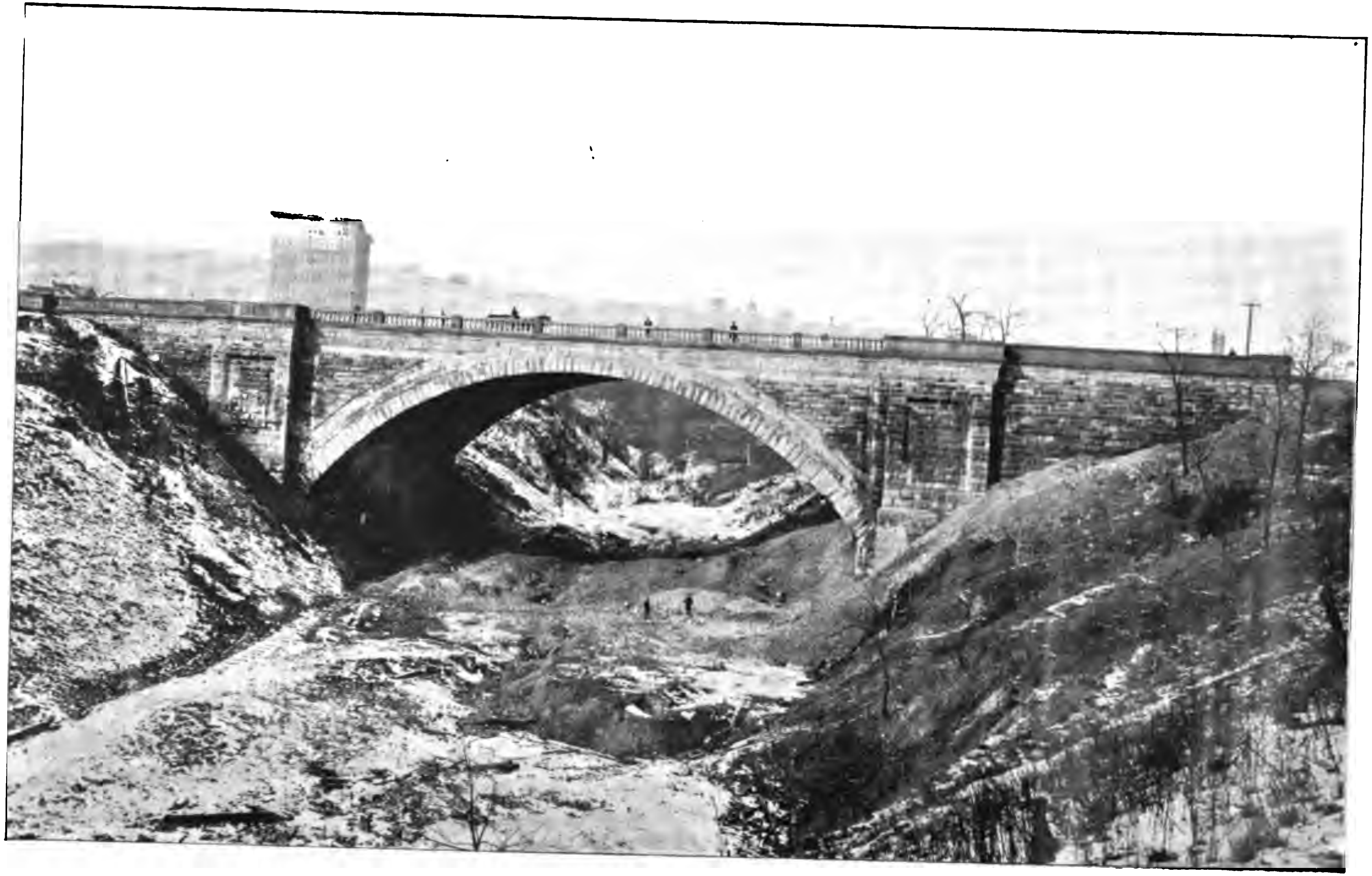
MEMORIAL BRIDGE AND ARCH, HARTFORD, CONN.



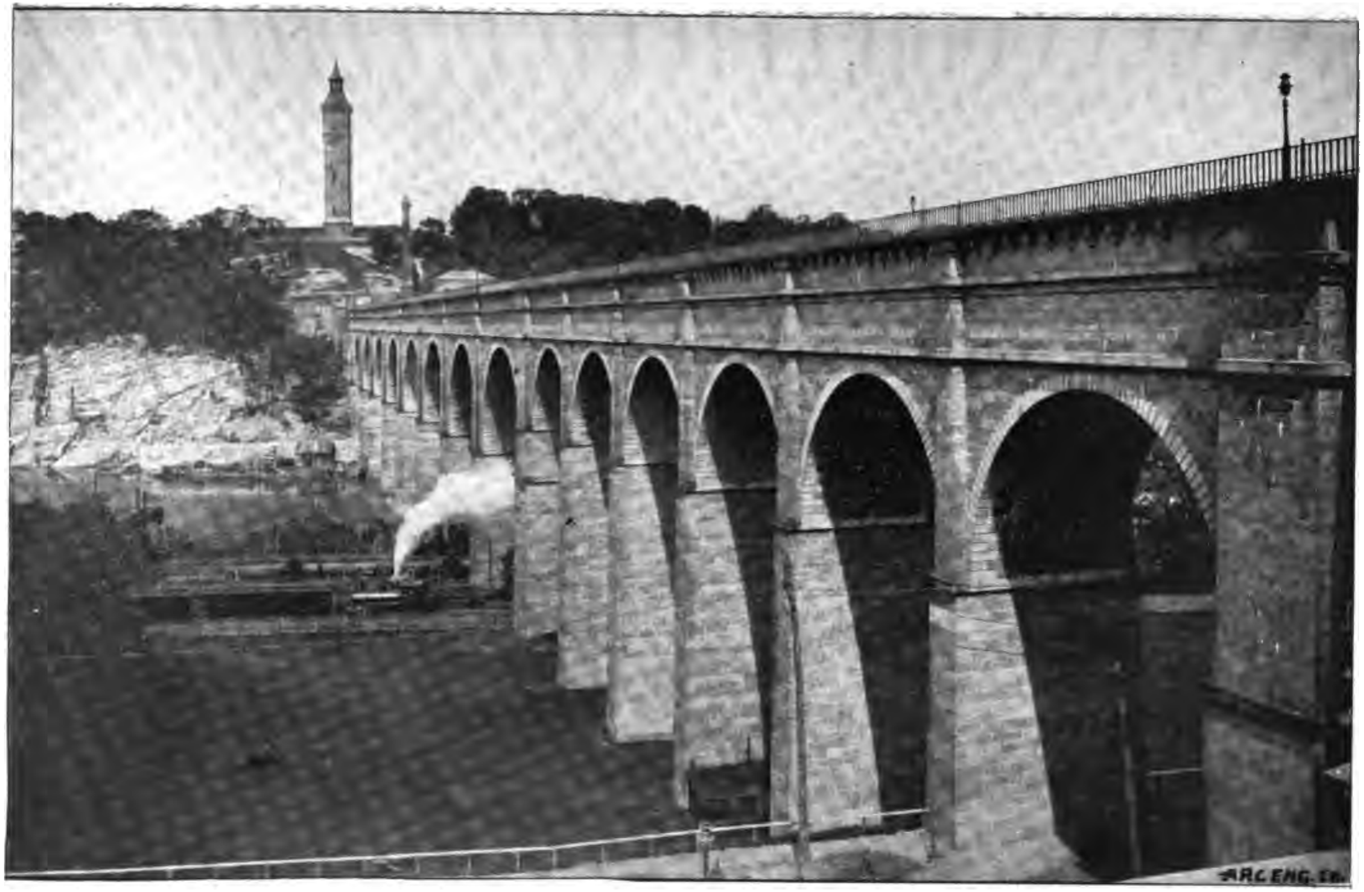
THE EAST BRIDGE, ELYRIA, OHIO.



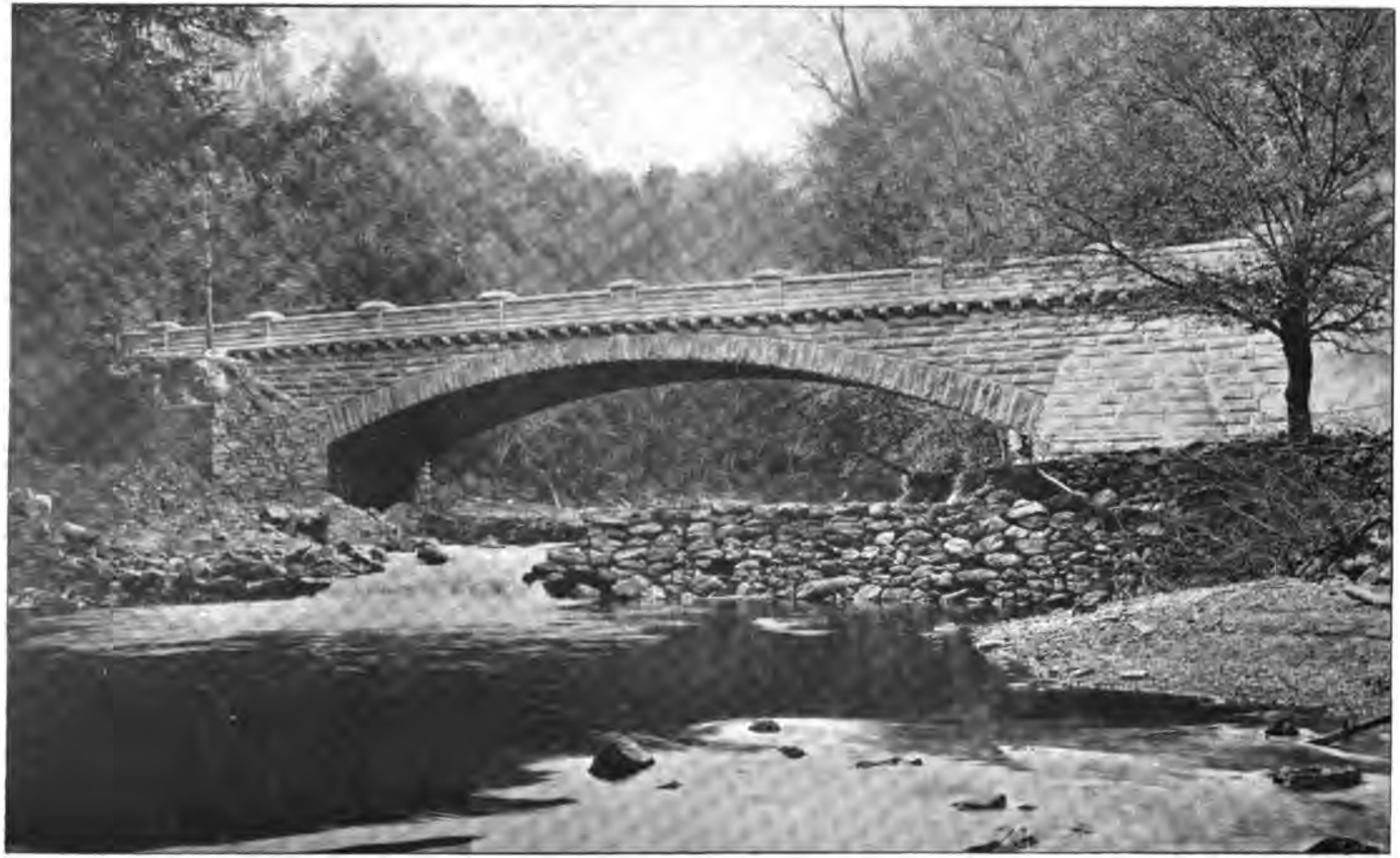
THE WEST BRIDGE, ELYRIA, OHIO.



SCHENLEY PARK ARCH, PITTSBURG.



HIGH BRIDGE, CROTON AQUEDUCT, NEW YORK.



WISSAHICKON ARCH, FAIRMOUNT PARK, PHILADELPHIA.

ENGINEERING STUDIES.

INTRODUCTION.

This collection of photographic views of Engineering Works should be found valuable alike to the practicing engineer and to the student.

Short descriptions and criticisms are appended to point out the good and the bad features of the designs, with the view of bettering the character of future engineering structures. A stone arch is very often regarded as a work of art so æsthetic, that it cannot be injured in appearance by careless detailing. Never was there a greater mistake than this, nor one more frequently made.

The intention is to bring out a number of parts forming a series which will include, in addition to stone arches, Bridge Approaches of Masonry, Bridge Towers and Portals, Notable Bridge Piers, Tunnel Portals and other engineering works of like character.

There will be six parts devoted to stone arches of several countries, and six or more parts devoted to miscellaneous structures.

AMERICAN STONE ARCHES.

THE CABIN JOHN ARCH.

THE largest stone arch ever built was the one constructed over the river Adda at Trezzo, by order of the Duke of Milan, about the year 1380. It had a span of 251 feet at low water, but it was destroyed in 1427, and now only about 24 feet of the arch ring, near each haunch, remains.

The largest one in existence at the present time, is the Cabin John bridge and aqueduct over Rock Creek, at Washington, D. C. It was designed by Gen. M. C. Meigs, and has a span of 220 feet, a rise of 57 feet, while the roadway of 20 feet width is 101 feet above the stream. The arch ring is of granite, six feet deep at the crown and four feet at the center; the spandrels are of sandstone, laid partially with radial joints. The splendid architectural effect is due to the proportions and to the relief afforded by the projecting courses at the roadway, which gives a cornice-like effect in entire harmony with the whole design. This can best be expressed by quoting from what Fergusson has to say in his "History of Architecture," regarding the efforts of the engineer at architectural effects.

"If this is all that can be done with bridges, (their decoration with inappropriate details) it is far better that they should be left, like most of those recently built, to tell their own tale without any ornament whatever. A long series of tall arches is so beautiful an object in itself that it is difficult to injure it; but occasionally a slight moulding at the impost, a bold accentuation of the arch, and bold marking of the roadway render those beautiful which otherwise may only be useful in appearance."

THE WHEELING STONE ARCH.

THE Wheeling stone arch bridge is one of the largest stone arches in the United States, having a span of 159 feet. The intrados is the arc of a circle, with a rise of twenty-eight feet. The depth of keystone is 4′ 6″. Longitudinal arched voids are employed underneath the roadway.

The engineers of the work were Hoge & White, the bridge being completed in 1893. The large span marks the structure as a notable piece of engineering work, and the detail of the parapet is very pleasing in appearance, although very simple in design. The coping with the supporting corbels is also very effective. Berea stone was used for most of the work, which amounted to about 9,000 yards, there being 6,000 yards of dimension stone. The cost of the bridge was $130,000.

The meeting of two straight grades at the center of the span is hardly the best solution possible for giving increased waterway, although plenty of precedent can be found for such an outline. A much more pleasing method would have been to use a parabolic curve for the longitudinal profile of the roadway and coping.

Had the offset in the retaining wall been made at the springing of the arch, as a division between the spandrel and retaining walls, it would have been more logical and the effectiveness of the structure as an architectural work much heightened.

HARTFORD MEMORIAL BRIDGE AND ARCH.

ONE of the handsomest stone arch bridges in the United States is the brownstone structure in Bushnell Park, at Hartford, Conn. Its effectiveness is largely due to the Memorial Arch, over the driveway leading up to the Capitol building.

The bridge was constructed originally in 1850, of Portland brownstone, and at a cost of about $15,000. Of the five arches, each having a span of twenty-five feet, the three center ones are semi-circular, while the two end ones are three center, with radii of 8½ feet and 14½ feet. The original width of the bridge was thirty-five feet, but in 1885 it was rebuilt to match the Memorial Arch, and the width increased to forty-one feet extreme, or with a roadway of twenty-eight feet and two sidewalks of four feet each. The widening was accomplished by tearing down the spandrel-walls to the top of the arch rings and supporting the added width by elegant stone brackets, adding much to the beauty of the bridge; while the design was made to harmonize with the Memorial by a parapet railing of elegant design.

The remodeling of the bridge cost $11,287, while the cost of the Soldiers' Memorial was $60,000. This was executed in brownstone and terra cotta, from the designs of Mr. Geo. Keller, a prominent Hartford architect. The two structures, when considered as a whole, form one of the most notable of monumental works.

THE ELYRIA ARCHES.

THE streams at Elyria, Ohio, have solid rock banks and beds, and the skewbacks for the eastern and western stone arches are cut in the solid rock of the banks. The situations are very picturesque and the falls below the western bridge, forty feet high, add much to the view.

The eastern arch is the third largest stone span in the United States and was constructed from the plans of E. C. Kinney in 1886; the span being 150 feet, the rise 24 feet, the width over all 32 feet, while the depth of the arch ring at the springing is 4 feet 6 inches and at the keystone 3 feet 9 inches. In the view of this arch, a beautiful two-span stone bridge on the Lake Shore Railway can be seen in the background.

The western arch was designed by E. S. Jackson and E. M. Bunce and was built in 1894. This span is the fifth largest in the United States, having a span of 112 feet, a rise of 19 feet 6 inches, a width across the arch ring of 38 feet, and a width on top of 44 feet. The skewbacks are from 4 to 8 feet above the bed of the stream, the arch ring having a depth at the keystone of 3 feet 6 inches.

Both arches are constructed with first-class rock-faced masonry, the stone being Elyria sandstone, quarried in the vicinity. The width of both arches has been increased by projecting corbel courses and coping, which only serve to intensify the shallow depth at the center. Had separate corbels been substituted for the corbel course on the large span, and for the lower corbel course on the small one, giving the effect of dentils, the appearance at the center would have been much improved. A stone parapet would have been a still further improvement in this respect.

While having the graceful architectural appearance one would expect in arches of such bold outline, they are nevertheless somewhat severe in design. This effect has been lessened somewhat by the addition of the consoles on the eastern arch, which also afford retreats on the sidewalks.

THE SCHENLEY PARK ARCH.

THE stone arch bridge recently completed in Schenley Park at Pittsburg is known as the Bellefield Bridge. It was designed by H. B. Rust, Engineer of Schenley Park, and is one of the most elaborate stone bridges in this country.

It has a span of 136 feet 7 inches and a width across the soffit of 82 feet. The roadway is 60 feet in width, while the two sidewalks have a width of ten feet each. The depth of keystone is four feet.

The arch is a very bold one, and the general design leaves little to be desired, while the balustrade is a most elegant piece of work. It is, however, unfortunate that the abutments and the spandrels were decorated with the paneling, as the apparent size of the arch is very much reduced by these details which have been characterized by Fergusson in a criticism of the Chester bridge as a mistaken application.—"by exaggerating his details, the bridge has been dwarfed in exactly the same manner as the basilica." * * "It is far better that we should be content with plain, honest, solid but useful erections, than that our buildings should be adorned on the mistaken principles which have hitherto been supposed to constitute the Art of Architecture."

HIGH BRIDGE, CROTON AQUEDUCT.

THE most notable stone bridge in the United States, not on account of the size of the spans, but because of its height, chaste design and monumental character, is the structure which carries the Croton Aqueduct over the Harlem River at New York City, from the mainland to Manhattan Island. The erection of the remarkable Washington Bridge, close to it, with its great steel spans, instead of detracting from its appearance as might be expected has only enhanced it.

The original intention was to carry the water across the river by a siphon pipe line through a tunnel, and, while the estimated cost was much less than for a high bridge, the uncertainties were so great as to cause its abandonment.

The location is a very beautiful one, the south shore being an abrupt bluff of solid gneiss rock, crowned with trees.

The requirements of navigation made it necessary to have a clear height of 100 feet above the river, and openings of 80 feet in width. The top of the parapet is 116 feet above high water, while there are eight semicircular arches of 80 feet each over the river, one arch of 50 feet in the Manhattan approach and six arches of 50 feet span in the opposite one.

The river is 620 feet in width at ordinary high water, the distance up to the springing of the arches being 60 feet, or 95 feet above the lowest foundation. The total length of the bridge is 1,460 feet, and it originally carried two cast-iron pipes, 3 feet in diameter, to convey the water, their use being with the object of preventing leakage, which would eventually injure the bridge. When it was desired to increase the carrying capacity a third pipe, 7 feet 6 inches in diameter, was added.

The structure was designed under John B. Jervis, Chief Engineer of the Croton Aqueduct, and was let at a contract price of $737,755. It occupied five years in building, being completed in 1842.

The arch ring is finely accentuated, but, unfortunately, the tailing of the ring stones does not match with the courses in the spandrels. The piers, spandrels and parapets have a batter of 1 in 48, the width across on top of the parapets being 21 feet. The length of the piers is greater than the width of the arches, and counterforts are carried up with good effect. The belt course directly above the voussoirs is in entire harmony with the cornice above, which is formed by ornamental corbels supporting the coping, thus making a portion of the footways on each side.

The footways are protected by iron railings of light design, which, however, appear well, owing to the great depth of masonry above the extrados. The difference in the height of the springing of the 50 feet spans and the 80 feet spans is taken care of in a very appropriate manner by the two coping courses on the piers which are common to both.

The water tower of elegant design adds much to the architectural effect, which is not much marred by the well-designed stack. While many European structures are more expensive and more elaborate, High Bridge compares favorably with them, and will remain for scores of years, a credit not alone to the engineer who conceived it, but to the City of New York as well.

THE WISSAHICKON ARCH, PHILADELPHIA.

THE bridge in Fairmount Park, Philadelphia, over Wissahickon Creek is a very handsome structure, having been built from the design of General Russell Thayer, chief engineer of The Fairmount Park Commission, at a cost of $27,743, including the removal of the old bridge.

The arch is on a skew of 69 degrees 26 minutes, which is taken up by arch rings, four feet wide each. The span of each ring is 106 feet 6 inches, the clear span of the arch 105 feet and the rise 11 feet. The spring of the arch is about six feet above the surface, at which point the arch ring has a depth of 4 feet 6 inches, while the depth of keystone is 3 feet.

The roadway 25 feet in width and the two sidewalks of 5 feet width each are paved with asphalt.

The stone of which the arch was built was quarried about one-half mile from the site and is a dark colored gneiss. The stone work is quarry-faced ashlar, with a one-inch chisel draft at each joint, thus making a two-inch draft at each joint. This gives a very fine appearance to the work.

The shallow depth at the center is relieved by the solid parapet, which has dressed stone coping, post and caps, and which is supported on a coping, carried by well proportioned modillions.

The symmetry of the design is unfortunately spoiled by the character of the bank at the left end, which is the more to be regretted as the right abutment is a most suitable and elegant arrangement.

ENGINEERING STUDIES

PART III

ENGLISH STONE ARCHES

By CHARLES EVAN FOWLER, M. Am. Soc. C. E.

◆

> "Whoever thinks a Faultless piece to see,
> Thinks what ne'er was, nor is, nor e'er shall be."
> * * * * * * * * *
> "Content if hence th' unlearn'd their wants may view,
> The learn'd reflect on what before they knew."
> —*Pope.*

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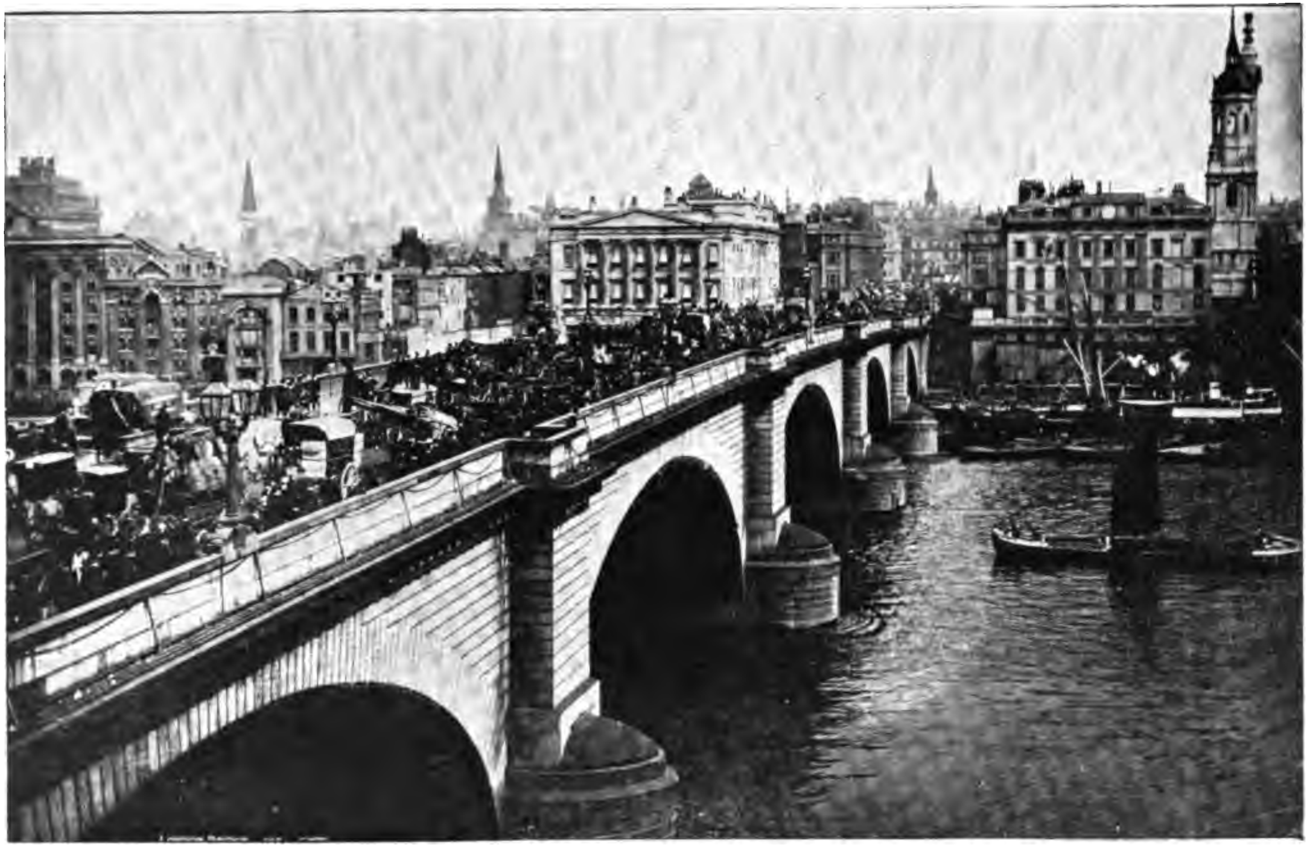
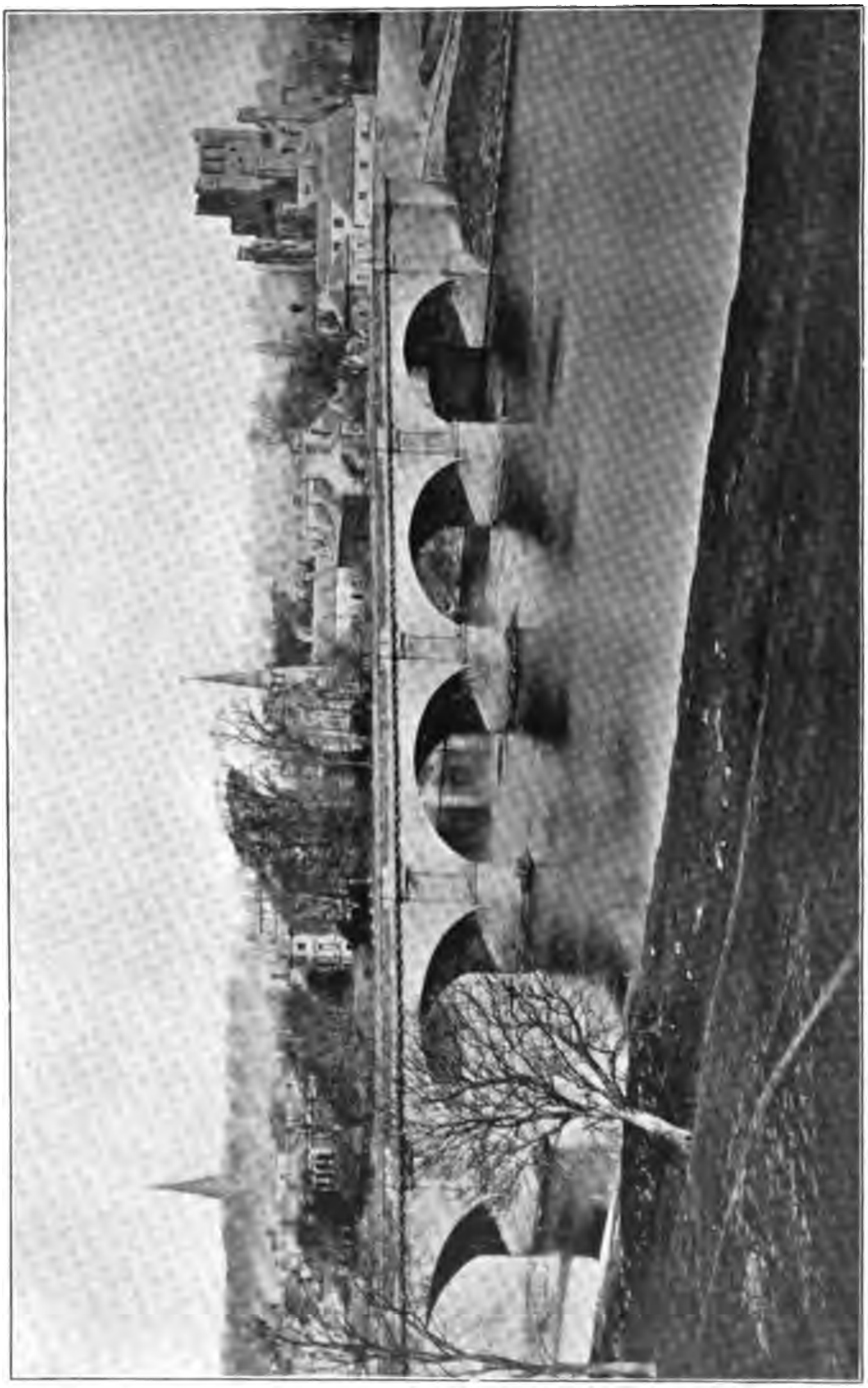
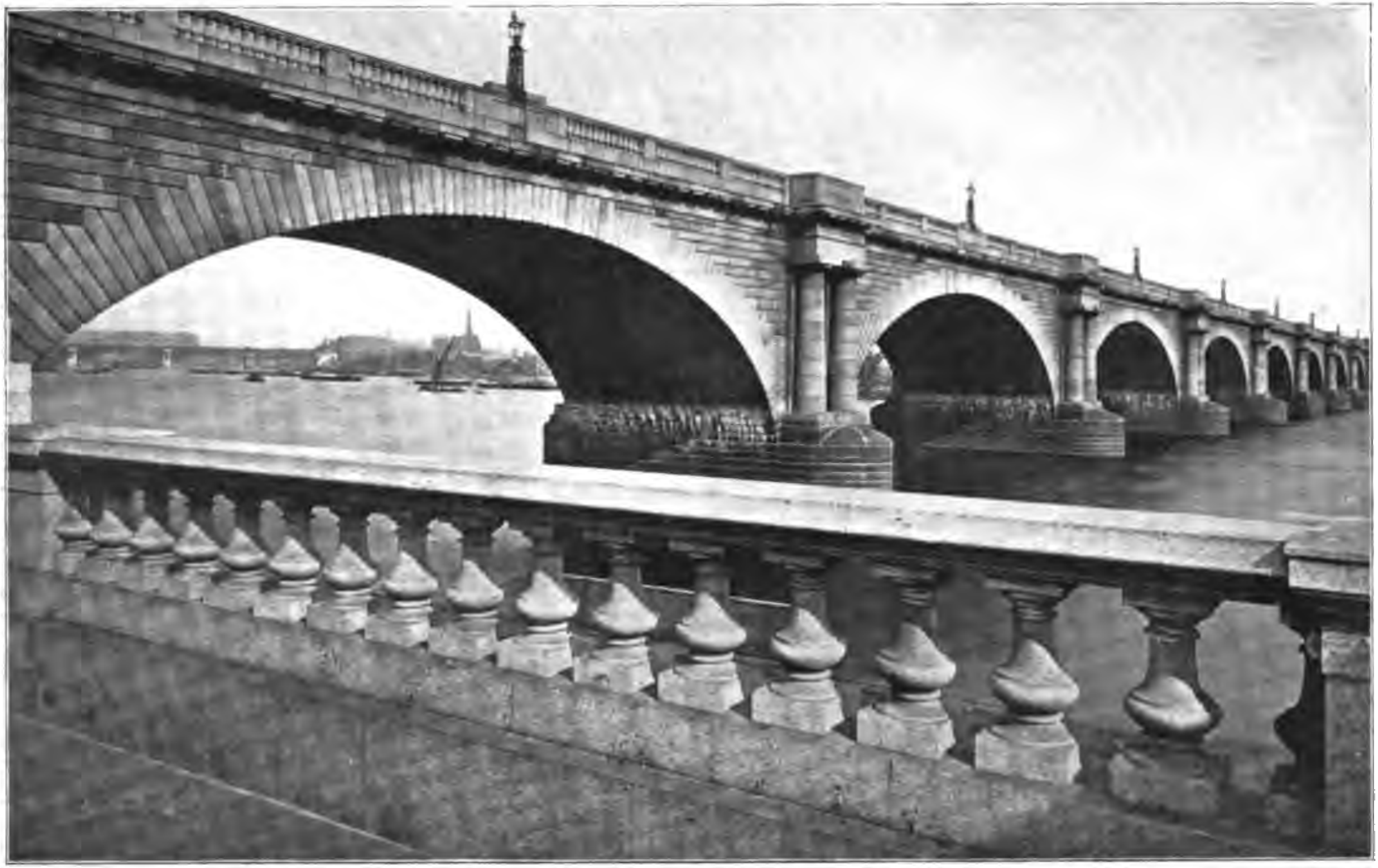


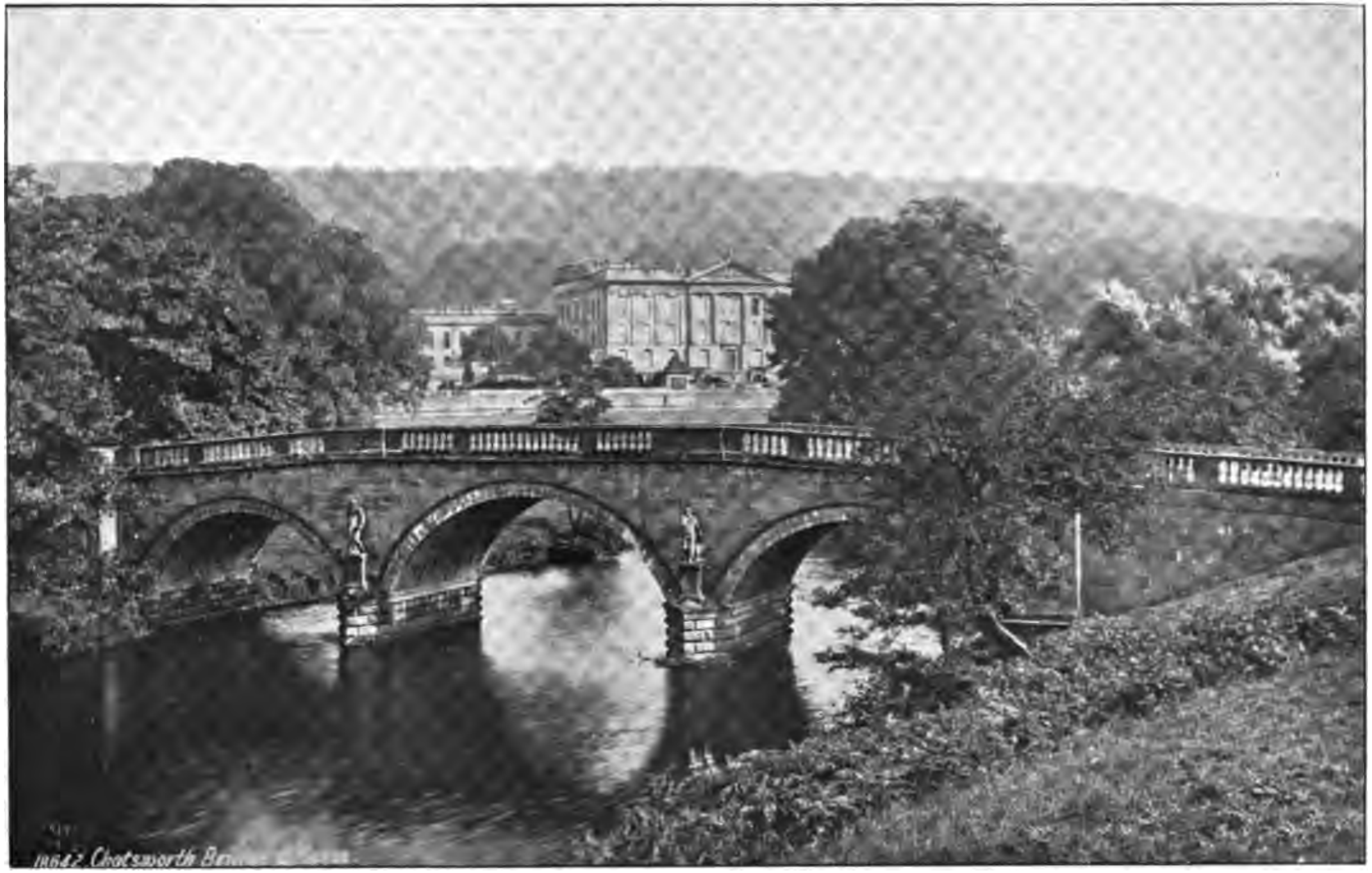
LONDON BRIDGE, LONDON, ENG.



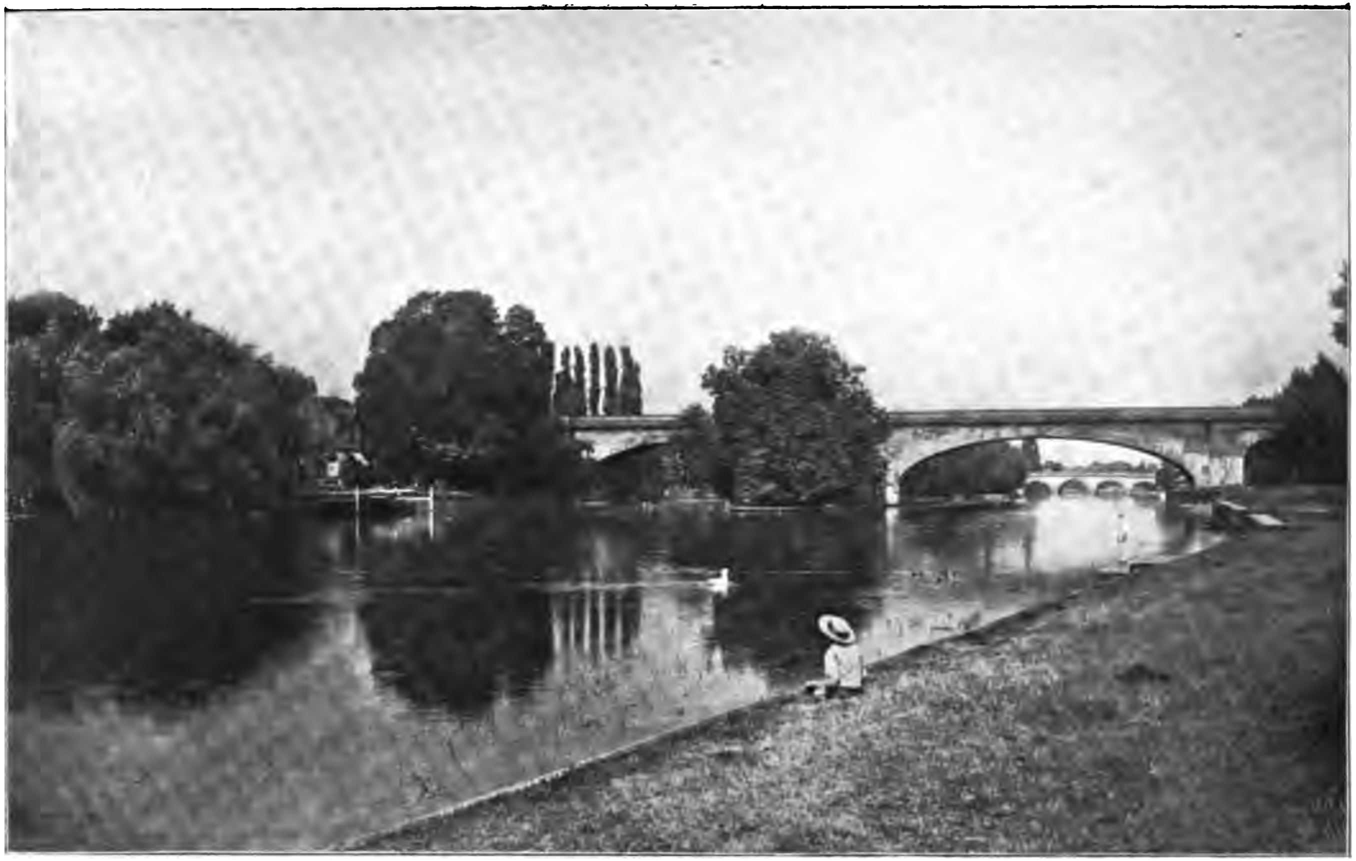
THE KELSO BRIDGE OVER THE TWEED.



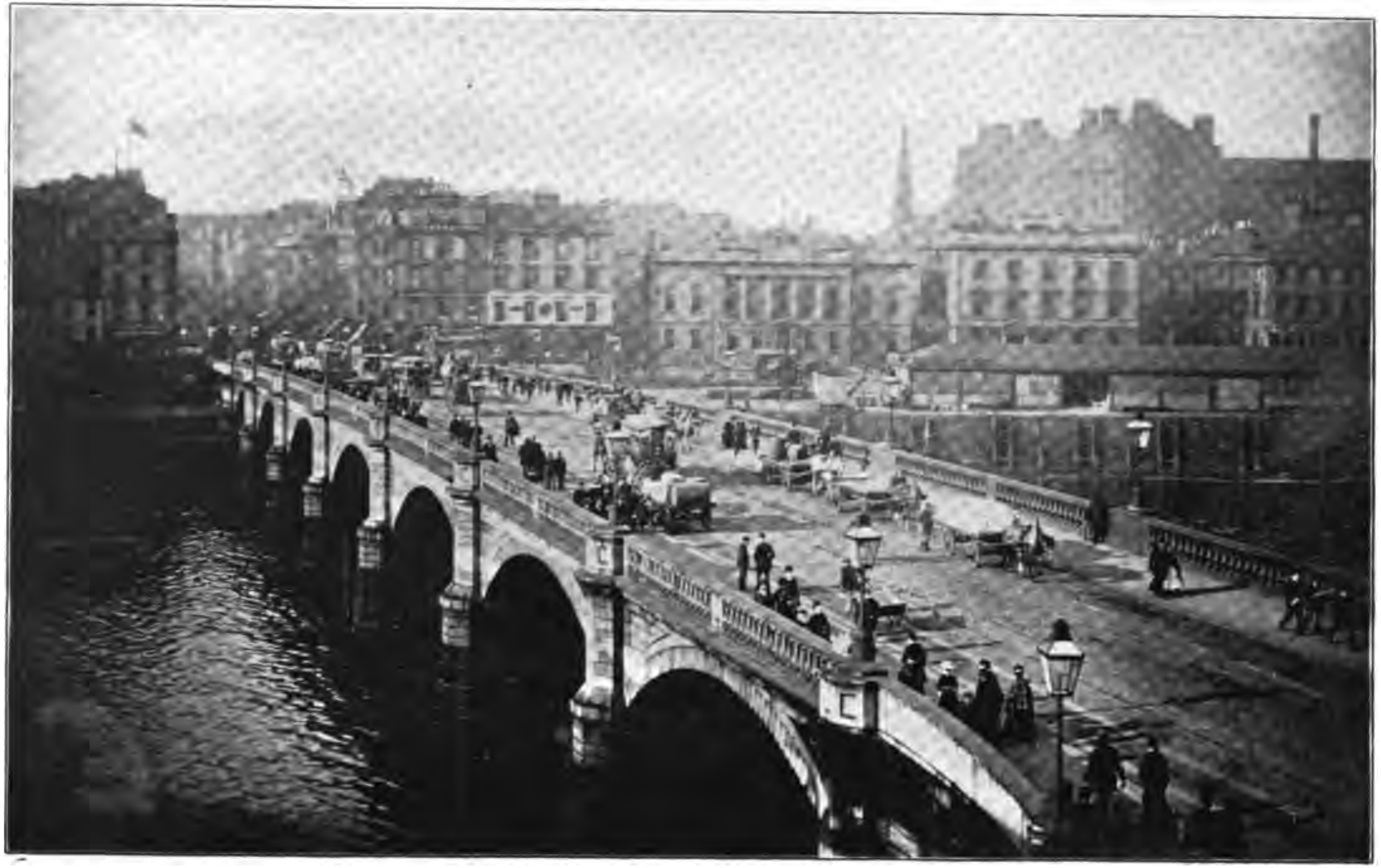
WATERLOO BRIDGE OVER THE THAMES.



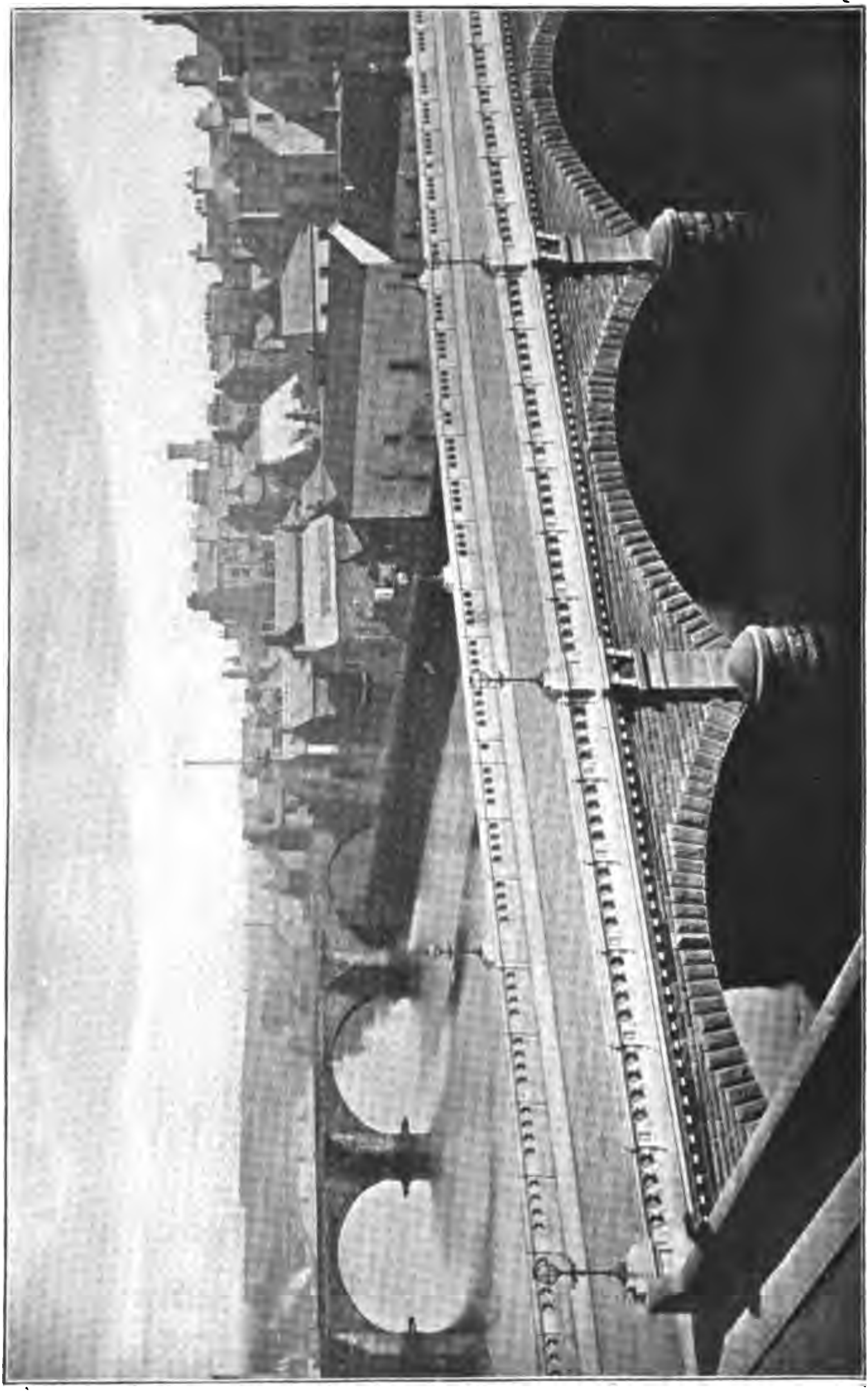
THE CHATSWORTH BRIDGE AND HOUSE, ENGLAND.



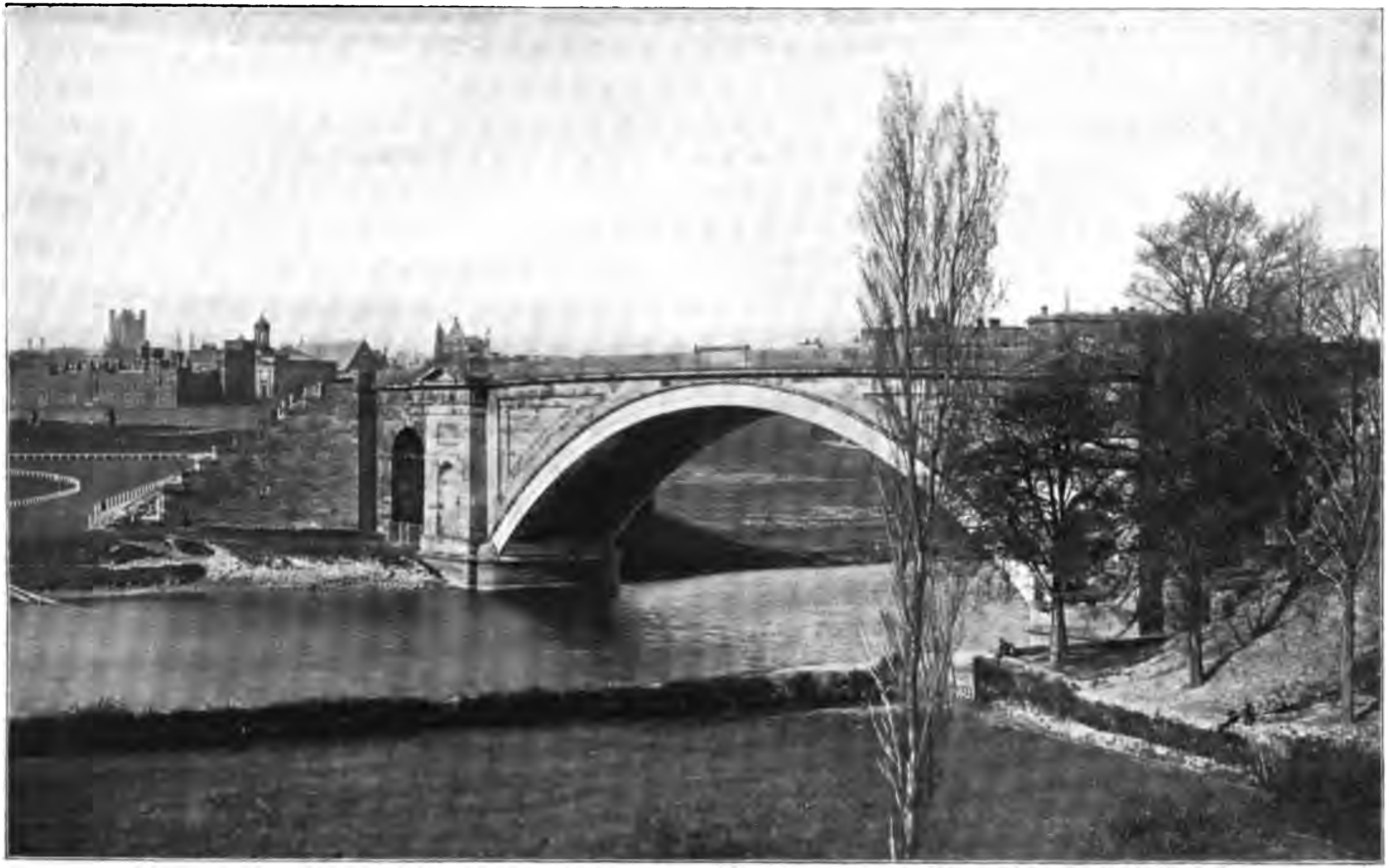
THE MAIDENHEAD BRIDGE, MAIDENHEAD, ENG.



THE BROOMIELAW BRIDGE, GLASGOW.



THE NEW BRIDGE OF AYR.



THE GROSVENOR OR CHESTER DEE BRIDGE.

LONDON BRIDGE.

ONE of the most renowned of modern stone arch bridges is the new London over the river Thames. It is also one of the most chaste and harmonious designs of the many stone bridges that have been built the world over, and was Rennie's masterpiece. The lack of waterway under the old bridge had occasioned great public controversy, and of the many plans proposed, the one from which the bridge was constructed seemed to meet best the needs of the river, of navigation, and for a structure which should be a work of architecture.

There are five spans of elliptical outline, the center one having a span of 152 feet, a rise of 37.7 feet, a depth of arch ring at the keystone of 4.8 feet and at the spring of 10.0 feet. The two spans on either side of the center one are 140 feet each, with a depth at key of 4.6 feet and at spring of 9.0 feet. The two shore spans have a span of 130 feet each, a depth at key of 4.5 feet and at spring of 8.5 feet.

The piers were founded in cofferdams, one of which was carried 29 feet 6 inches below low water. The stone used was of granite, and the masonry, up to the springing of the arches, was specified to be ashler in horizontal courses of from 15 to 24 inches thickness. All of the arch stones were to be headers, unless the engineer allowed stretchers to be used. At the intrados they were to be 18 inches in thickness and the faces dressed smooth and straight. The spandrels between the arches are of granite and the ring stones of the arch are tailed into the spandrel courses.

The cornice and parapets are also of granite, finely dressed and jointed, and none of the stones belonging to the cornice, plinth, dado, or coping were allowed less than 4 feet 6 inches long. All these stones were to be free from flaws of any description.

The centers for turning the arches were composed of eight ribs for each span, each rib being a truss. They were framed at the Isle of Dogs, were floated to the bridge site and raised from a large barge into place by means of screws and the tide. On these ribs were 7-inch plank laid close to carry the masonry.

The first arch laid was allowed to stand the entire winter, and when the wedges were struck, the arch sank an inch and a half, but the curve was not broken.

The bridge has two 9-feet sidewalks and a roadway, making the entire width, face to face of masonry, slightly in excess of 56 feet. The roadway is supported on longitudinal arched voids and has an easy grade.

The beautiful elliptical outline of the arches is but one of many details by which an appearance of elegance is obtained. The starlings of almost perfect design are coped and capped in an appropriate manner, and support counterforts, which are very effective in overcoming any tendency toward flatness of design. The parapet or cornice is supported by corbels, and while of the simplest design is in entire harmony with a most studied and effective piece of bridge architecture.

The unsightliness of the piping which is laid on top of the cornice would suggest the necessity in modern structures of providing a conduit for pipes, wires and other similar appurtenances of modern civilization.

The bridge, exclusive of land, houses, compensations, and law expenses, cost about two and one-eighth millions of dollars.

THE WATERLOO BRIDGE.

THIS structure, as is mentioned in the description of the Kelso bridge, was built by John Rennie, who used that one as his model for what is probably the most remarkable of English stone arch bridges. The roadway being nearly level for the entire length, adds much to the appearance of a work which is really monumental. There are nine semi-elliptical arch spans of 120 feet each, with a rise of 34.6 feet, the depth of the arch ring being 4 feet 6 inches at the key, and 10 feet at the springing. The keystone is not accentuated in any way, and all the arch stones tail into the spandrel courses in groups, all joints being chamfered to correspond with the spandrel masonry.

The piers, which were founded in cofferdams, have semi-circular ends, being 30 feet thick at the base, 20 feet at the spring, with a length of 87 feet. The broad abutments have staircases down to the river, are 40 feet thick at the base and 30 feet at the spring.

All the exterior masonry is of dressed granite, and the filling is of Cragleigh or Derbyshire stone. Over the spandrels are rows of columns to carry the roadway, which has a width of 28 feet, besides which there are two walks of 7 feet each.

The end of each of the long piers, supports two severely classic Doric columns, supporting an entablature, and it is almost a regret that such ornamentation is open to criticism as being misplaced, as has been done in describing other bridges with similar details. When compared, however, with the counterforts on the London bridge it is seen that nothing has been gained in appearance by the use of columns.

The whole structure is surmounted by a well-designed parapet and balustrade with finely detailed turned balusters. Over each keystone is "mis"-placed a lamp, which very much mars the otherwise grand effect of the bridge, and which should have been placed over the piers instead.

The uneven number of spans, the carefully worked-out design, the character of the engineering, and the great finish of the whole work, makes this one of the most notable of bridges and one which will bear careful study into the minutest details.

THE MAIDENHEAD ARCHES.

THE railway bridge at Maidenhead, England, constructed by Brunel, in 1837, is an example of the grandeur given to engineering works by simplicity of design. The two large arches are elliptical, with a span of 128 feet, a rise of 24.2 feet, and a depth of key of 5.3 feet.

The spandrels are built with longitudinal voids—the bridge being of brick laid in cement. The curve of the intrados is very graceful and the whole effect is one of boldness. The parapets are well proportioned and afford the relief necessary, while the abutments are finely accentuated by the twin pilasters.

The prevalence of such work gives an air of completeness to a landscape and one has reasonable expectation of seeing other evidences of civilization in its neighborhood; and this is not disappointed, as the arch bridge seen through the large span forms part of another landscape set in a frame of masonry.

KELSO BRIDGE OVER THE TWEED.

THE location of the Kelso bridge is near the junction of the Tweed and Tevoit Rivers, where the scenery is most beautiful. It was designed by Rennie, and is of practically the same style as his Waterloo bridge, which was built at a later date. There are five equal spans of 72 feet each and a rise of 20 feet 9 inches, while the width is 26 feet. The arches are elliptical, with the arch stones tailed into the spandrel courses. The piers have semi-circular ends and support two Doric columns and entablature, on which rests the cornice. The roadway is perfectly level throughout, and is guarded by solid parapets, with retreats over the piers. The abutments also have columns supporting the cornice, and quadrant concave wing walls.

The severeness of the design, together with the height above the stream, gives the structure an imposing appearance and makes it appear that the spans are quite large. The ruins of Kelso Abbey to the right adds materially to the view. This bridge was completed in 1799 and the Waterloo bridge begun in 1811. The Waterloo bridge had nine elliptical arches of 120 feet and was one of the first bridges constructed over the Thames with the roadway nearly level.

THE CHATSWORTH BRIDGE.

WHILE there is nothing especially remarkable about the Chatsworth bridge, it is a typical example of English Palace accessories in bridge engineering. As Chatsworth House is considered the most splendid private palace in England, it is to be expected that the bridge would be somewhat too ornate. It is almost entirely a piece of architecture, as the engineering problems involved in its construction are of a very simple character.

The piers are well proportioned, and are capped with elegant molded copings. The springing of the arch is well defined and the arch ring is neatly emphasized by a molded archivolt.

The statuary over the pier starlings is entirely out of place in bridge design, but it must be admitted to be in perfect harmony as part of a group of architectural works.

The beautiful coping and balustrade are of such elegant design as to be worthy of much study and imitation. The abutments are elegantly defined and it is to be regretted that a work otherwise so deserving of commendation, should have its beauty impaired by the broken profile of the roadway, which could easily have been avoided by a gentle curve and another element of elegance added.

BROOMIELAW BRIDGE, GLASGOW.

THIS bridge has seven segmental arches, the center span being 58 feet 6 inches and having a rise of 10 feet 9 inches, the two adjacent ones 57 feet 9 inches span and 10 feet 5 inches rise, the next ones 55 feet 6 inches span and 9 feet 8 inches rise, while the shore spans are 52 feet 3 inches. The piers range in thickness from 8 to 9 feet and have octagonal ends, supporting octagonal counterforts, which carry the pedestals and lamps. The bridge has two sidewalks and a roadway with two car tracks, making up a total width of 58 feet in the clear between parapets. The arch ring is composed of uniform ring stones with chisel draft on all edges, while the spandrels are paneled. The balustrade has turned balusters and a pilaster over each keystone. The piers and abutments are of freestone, while the face work of the arches and spandrels is of granite.

The bridge was designed by Telford, who is credited with having built upwards of eleven hundred stone bridges, having over twelve hundred arches.

The foundations were built in cofferdams having a five or six feet puddle chamber. Piles were driven for the foundations,, cut off to a level, and capped with grillage platforms on which to lay the masonry. The paving for the roadway is laid upon concrete, the sidewalks are of flat stone, the 12-inch curb of granite has the angle rounded off, while the gutter, also of granite, is 14 inches wide and has a triangular channel cut in it, 8 inches wide and 4 inches deep.

THE NEW BRIDGE OF AYR.

THE "Twa Brigs o' Ayr" have been made famous by the poet Burns, one of the bridges being the old one in the background which is now used only for foot passage, while the new one in the foreground occupies the site of the other, the present bridge being the third to occupy the same place. The bridge consists of five spans of small rise, the side spans being somewhat shorter than the other three. The arch stones are tailed into the spandrel courses in a very pleasing manner and the keystones accentuated by a pyramidal face. The piers have rounded ends, with appropriate coping and caps, and are surmounted by counterforts with molded tops. The dentiled cornice, while very plain, is of neat design, being broken over the piers by the ornamental brackets which support the pedestals of the balustrade.

The parapets or balustrades are of very beautiful design, that over each arch being divided into several sections by paneled pilasters, each section having four circular openings in the dado with other simple but effective decoration, except that the long spans have an extra panel at the center with only one opening. At the ends and over each pier there are pedestals carrying ornamental lamp posts.

The contrast with the old bridge is very great and is a striking illustration of the progress made in bridge design. Scarcely any fault is to be found with the appearance of the new bridge unless it is the lack of more prominent abutments at both ends, there being an appearance of the bridge having been crowded in between the river walls.

THE GROSVENOR BRIDGE.

THE fourth largest stone span in existence is the one built at Chester, England, over the river Dee, from the plans of Mr. Harrison, an architect of that city. It is known as the Grosvenor or Chester-Dee bridge. The span is exactly 200 feet, the rise 42 feet, the depth at key 4.5 feet, at spring 7.0 feet, while the roadway is 33 feet in width.

The following description of the bridge is taken from Cresy:

"The bridge is situated between the castle and the village of Overlegh, immediately at the head of the harbor, where the tide rises 12 feet at ordinary springs. The abutments are founded on the solid rock, except for a small portion, where it was necessary to pile. The arch is the segment of a circle whose radius is 140 feet, and the rise, or versed sine, 42 feet. The voussoirs at the crown are 4.5 feet deep, and increase toward the springing, where they are 7 feet. The center, executed by Mr. Trubshaw, the contractor, consisted of six ribs in width; the span of the arch was divided into four spaces by three piers, at regular distances, built up in the river, from which the timbers spread like a fan towards the soffit, so that each timber received its weight in the direction of its length; the lower ends of these radiating supports rested on cast-iron shoes, placed on the tops of stone piers, and the upper ends were bound together by two thicknesses of 4-inch plank, cut and arranged to follow the form of the arch; on these were laid the lagging or covering, 4½ inches thick, which was supported over each rib by a pair of folding wedges 16 inches long and 1 foot broad, tapering about 1½ inches; each course of voussoirs has six pair of striking wedges. The horizontal timbers of the center were 13 inches deep, and the six ribs were tied together transversely near the top by bolts of inch iron; the timber used was fir, and the quantity required about 10,000 cubic feet. When the center was removed the crown sunk only 2½ inches. The cost of the bridge was £42,400, and the approaches £7,500, making a total of £49,900."

In several previous examples, quotations from Fergusson's criticism on this bridge have been given, so that it would seem appropriate to quote in full what he has to say concerning it. While quite severe in tone, it must be said that personal inspection of the bridge invites respect for the bridge and for the designer.

Fergusson says:

"In all these cases the primary object of the engineer is use, not beauty; but he cannot help occasionally becoming an architect, and sometimes with singular success, though too frequently, when he ornaments, it is, as architects generally do, by borrowing features from the Classical or Mediaeval styles, or by some mistaken application of them, betraying how little he has really studied the problem before him.

"In illustration of these definitions, let us take the Dee bridge at Chester. As an engineering work, nothing can be nobler. It is the largest single span for a stone bridge in England, probably in the world; built of the best materials, and in a situation where nothing interferes with its beauty or proportions. Its engineer, however, aspired to be architect; and the consequence is, that instead of giving value to an arch of 200 feet span, no one can, by mere inspection, believe that it is more than half that width. In the first place, he introduced a common architrave moulding round the arch, such as is usually employed in domestic architecture, and which it requires immense thought to exaggerate beyond the dimensions of a *porte-cochere*. He then placed in the spandrels a panel 30 feet by 50, which, in like manner, we are accustomed to, of one-third or one-thirtieth these dimensions. He then, on his abutments, introduced two niches for statues, which it is immediately assumed would be of life size; and beyond this, two land-arches without mouldings or accentuations of any sort, consequently looking so weak as to satisfy the mind there was no difficulty in the construction.

"Had Mr. Harrison been really an architect, he would have rusticated these land-arches with Cyclopean massiveness, not only to continue the idea of the embankment, but also to give strength where it was apparently most needed; and would have avoided anything in the abutments that savored of life-size sculpture or of temple building. A Mediaeval architect would have pierced the spandrels with openings, thereby giving both lightness and dimensions to this part; or, if that was not mechanically admissible, he would have divided it into three or four panels, in accordance with the construction. The essential parts in the construction of a bridge, however, are the voussoirs of the arch; and to this the architect's whole attention should first be turned. If there had been fifty well-defined arch stones, the bridge would have looked infinitely larger than it now appears. With one hundred it would have looked larger still; but, if too numerous, there is a danger of the structure losing that megalithic character which is almost as essential as actual dimensions for greatness of effect. The true architect is the man who can weigh these various conditions one against the other, and strike a judicious balance between the different elements at his command. At Chester the builder has failed in this at every point, and by the same process which ruined St. Peter's. By exaggerating his details, the bridge has been dwarfed in exactly the same manner as the basilica.

"If this is all that can be done with bridges, it is far better that they should be left, like most of those recently built, to tell their own tale without any ornament whatever. A long series of tall arches is so beautiful an object in itself that it is difficult to injure it; but occasionally a slight moulding at the impost, a bold accentuation of the arch, and bold marking of the roadway render those beautiful which otherwise may only be useful in appearance."

ENGINEERING STUDIES

PART IV

FRENCH STONE ARCHES

BY CHARLES EVAN FOWLER, M. AM. SOC. C. E.

''Whoever thinks a Faultless piece to see,
Thinks what ne'er was, nor is, nor e'er shall be.''
* * * * * * * * *
'Content if hence th' unlearn'd their wants may view,
The learn'd reflect on what before they knew.''
—*Pope.*

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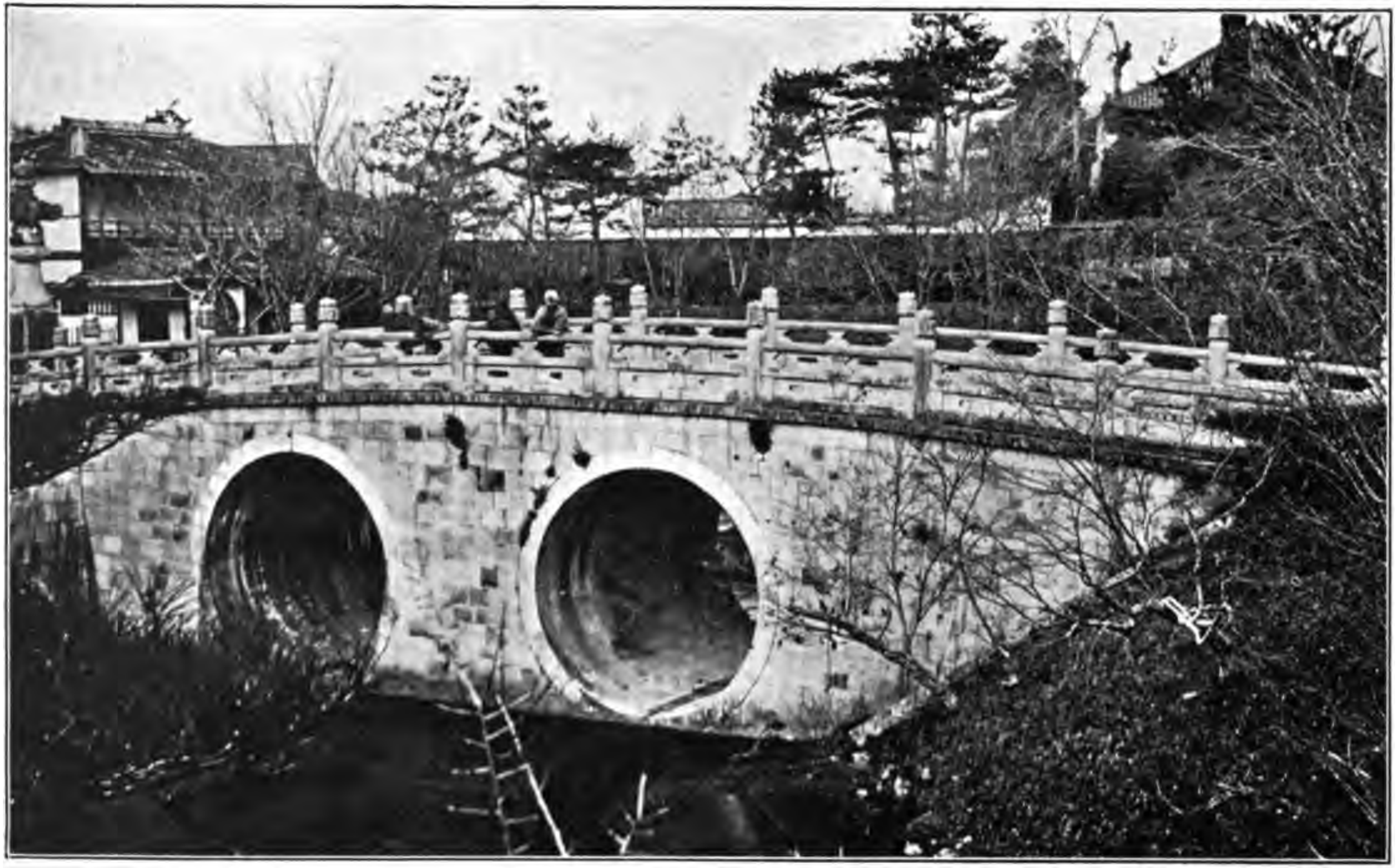
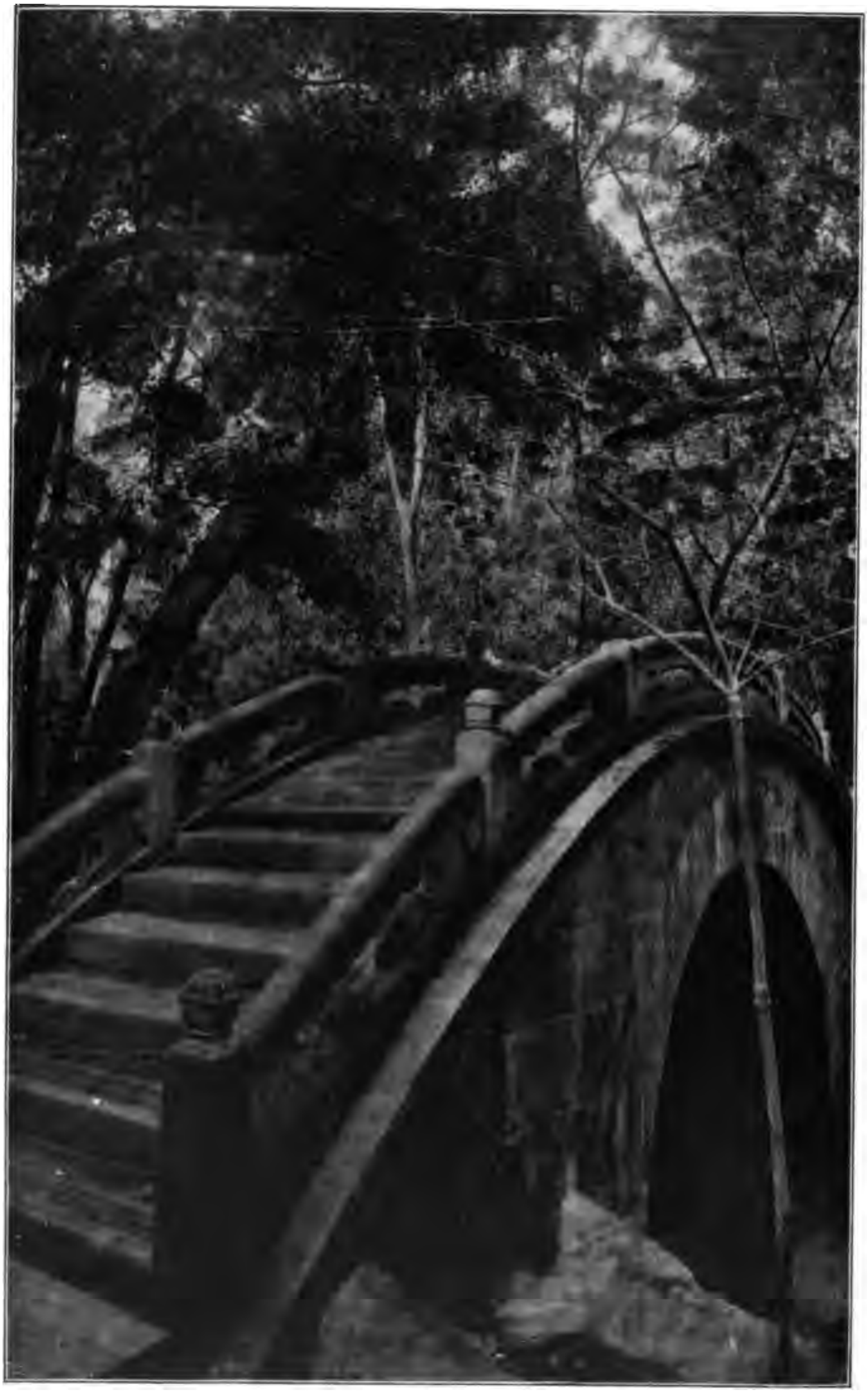
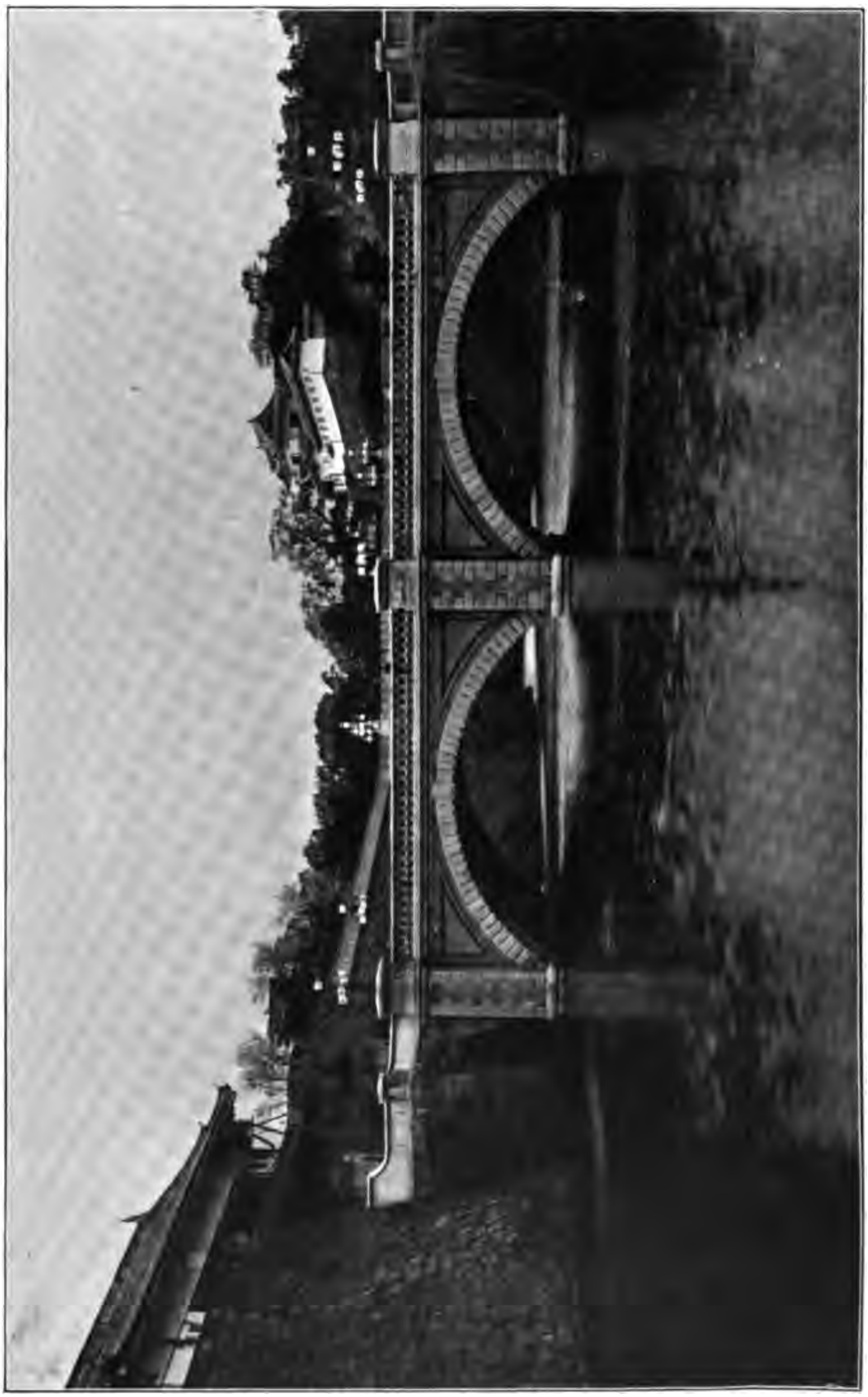


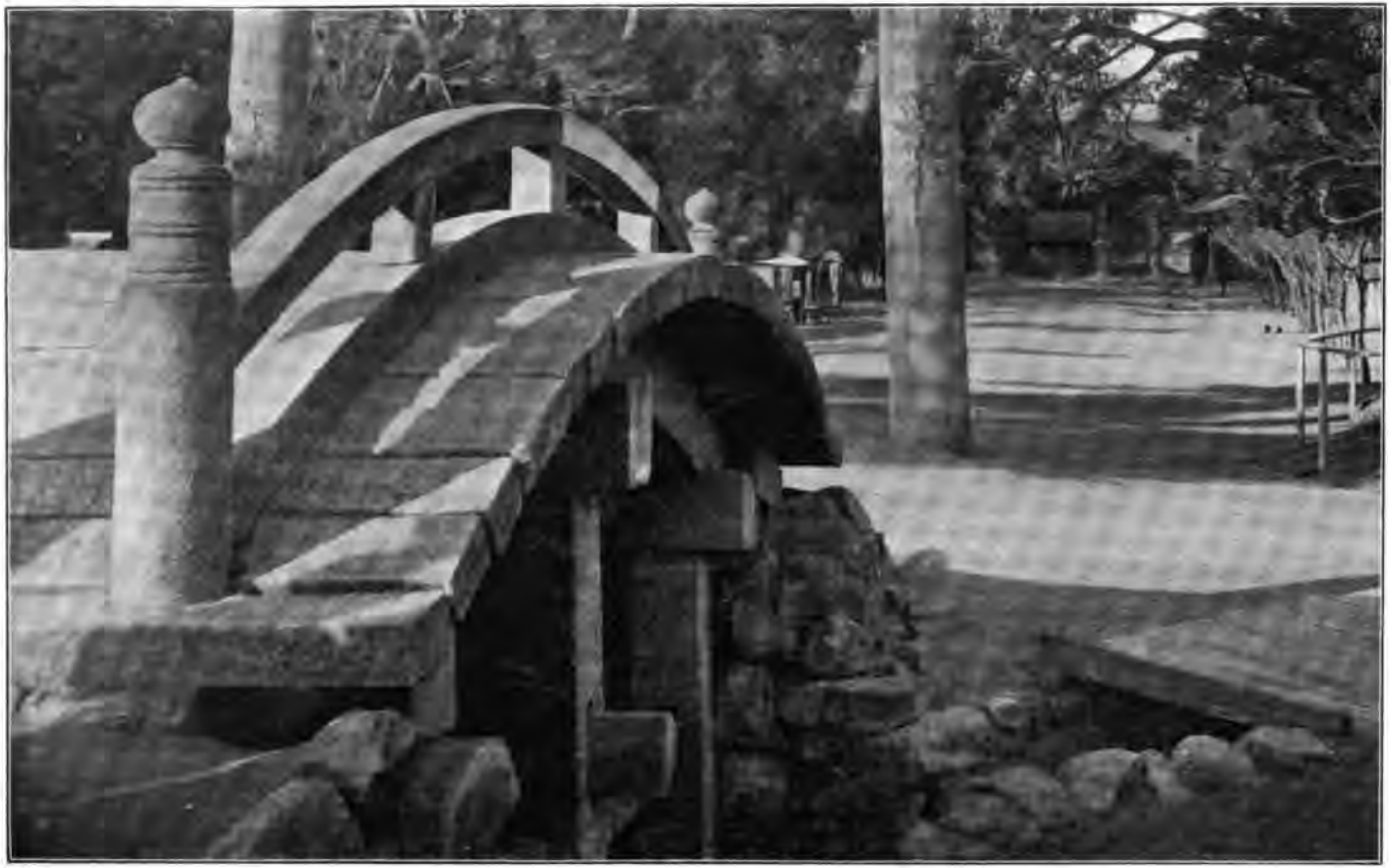
SPECTACLE BRIDGE, JAPAN.



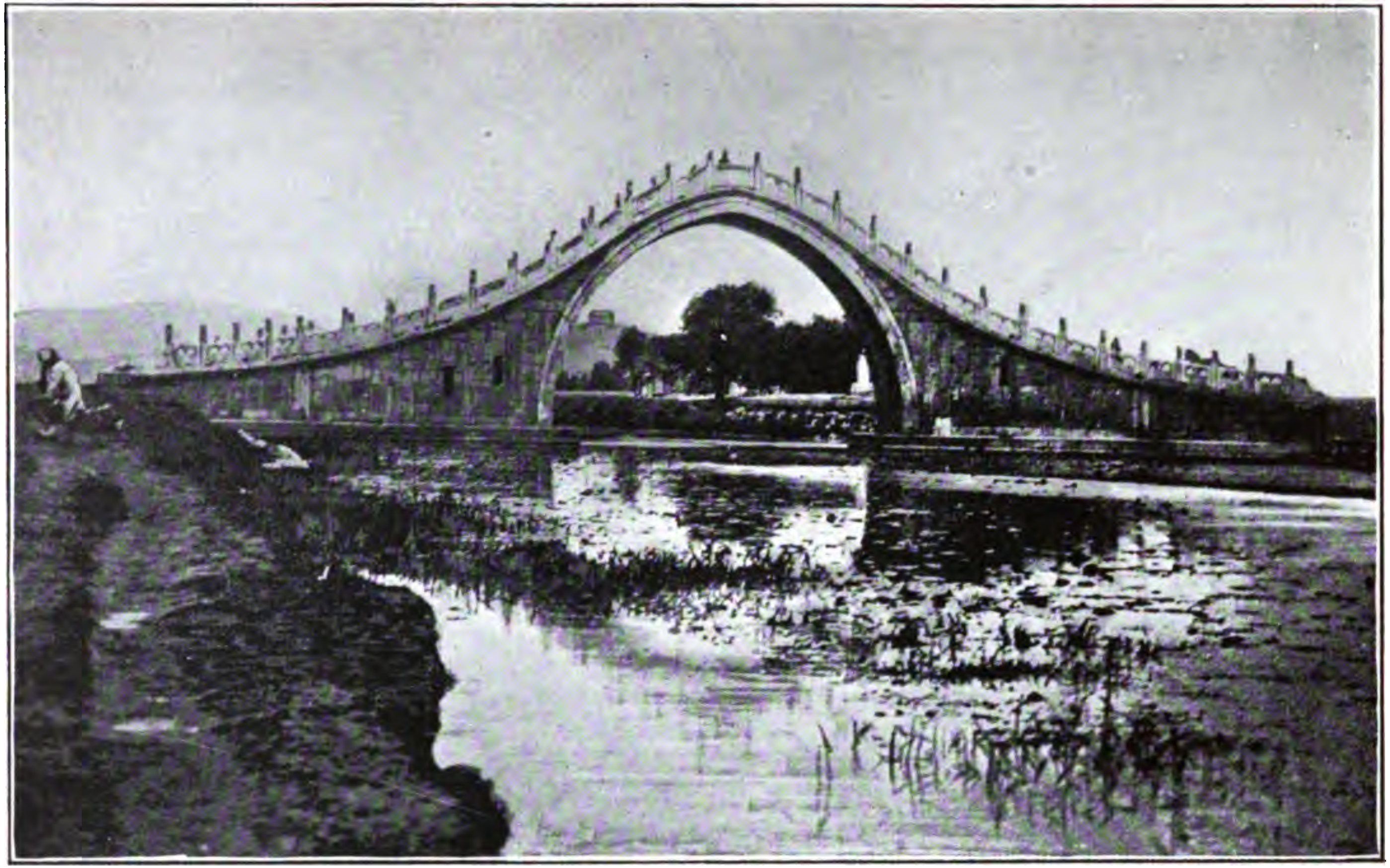
MITO GARDEN BRIDGE, TOKIO.



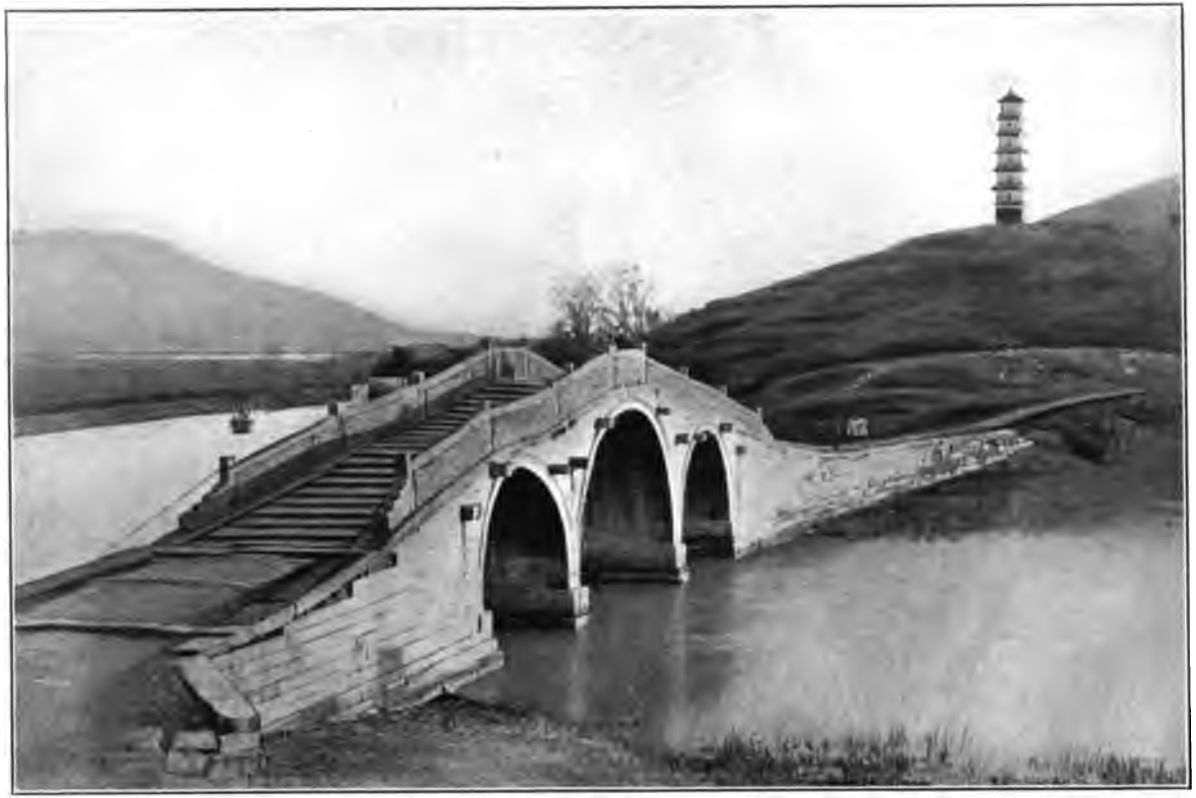
IMPERIAL PALACE BRIDGE, TOKIO.



ATSUTA BRIDGE, NEAR NAGOYA.

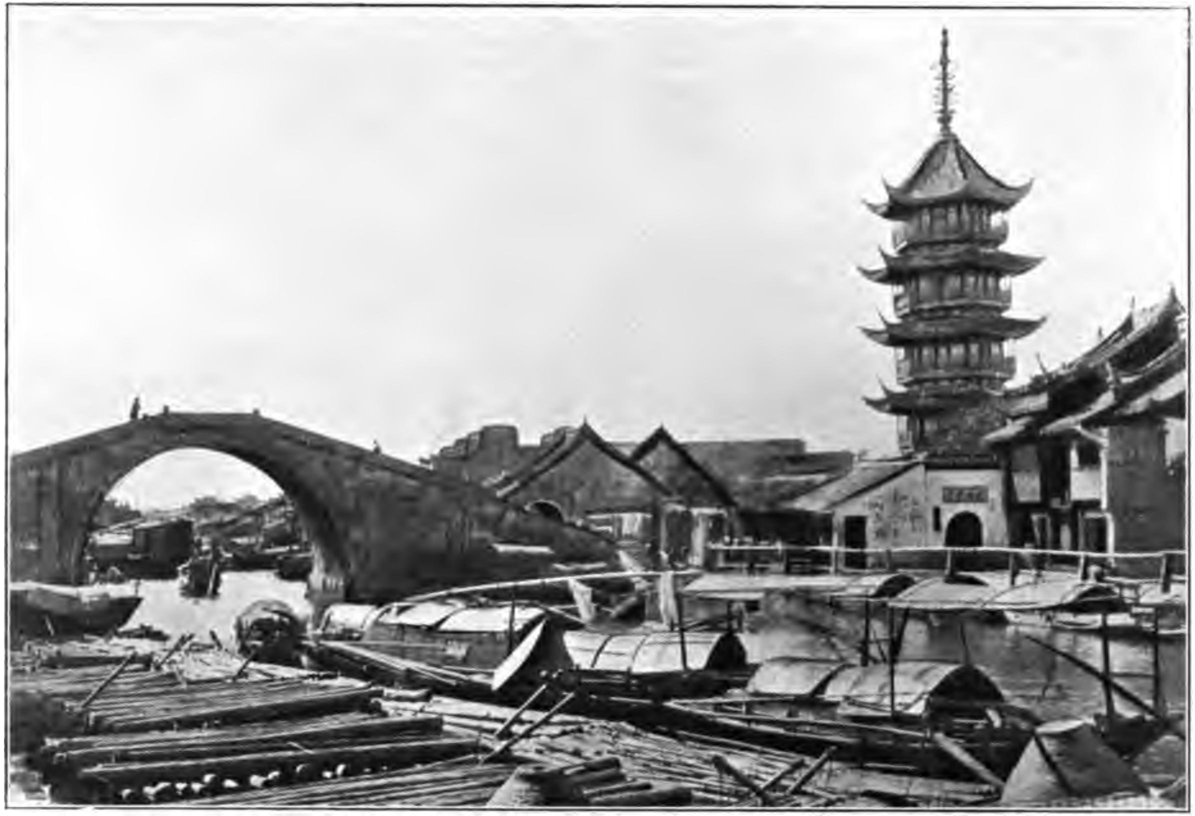


CAMEL-BACK BRIDGE, PEKIN, CHINA.



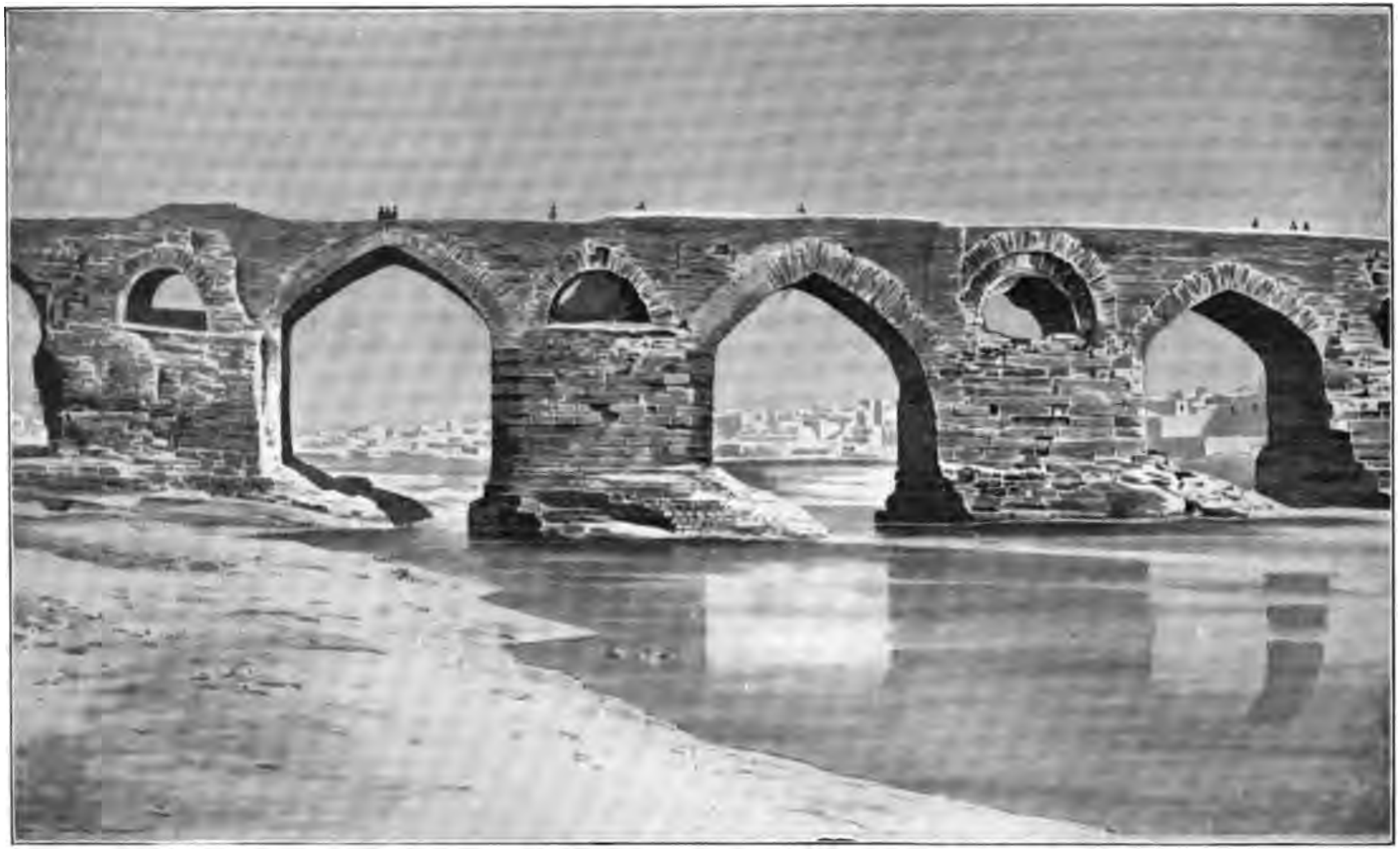
BRIDGE NEAR SHANGHAI, CHINA.

By courtesy of "Cassier's Magazine."

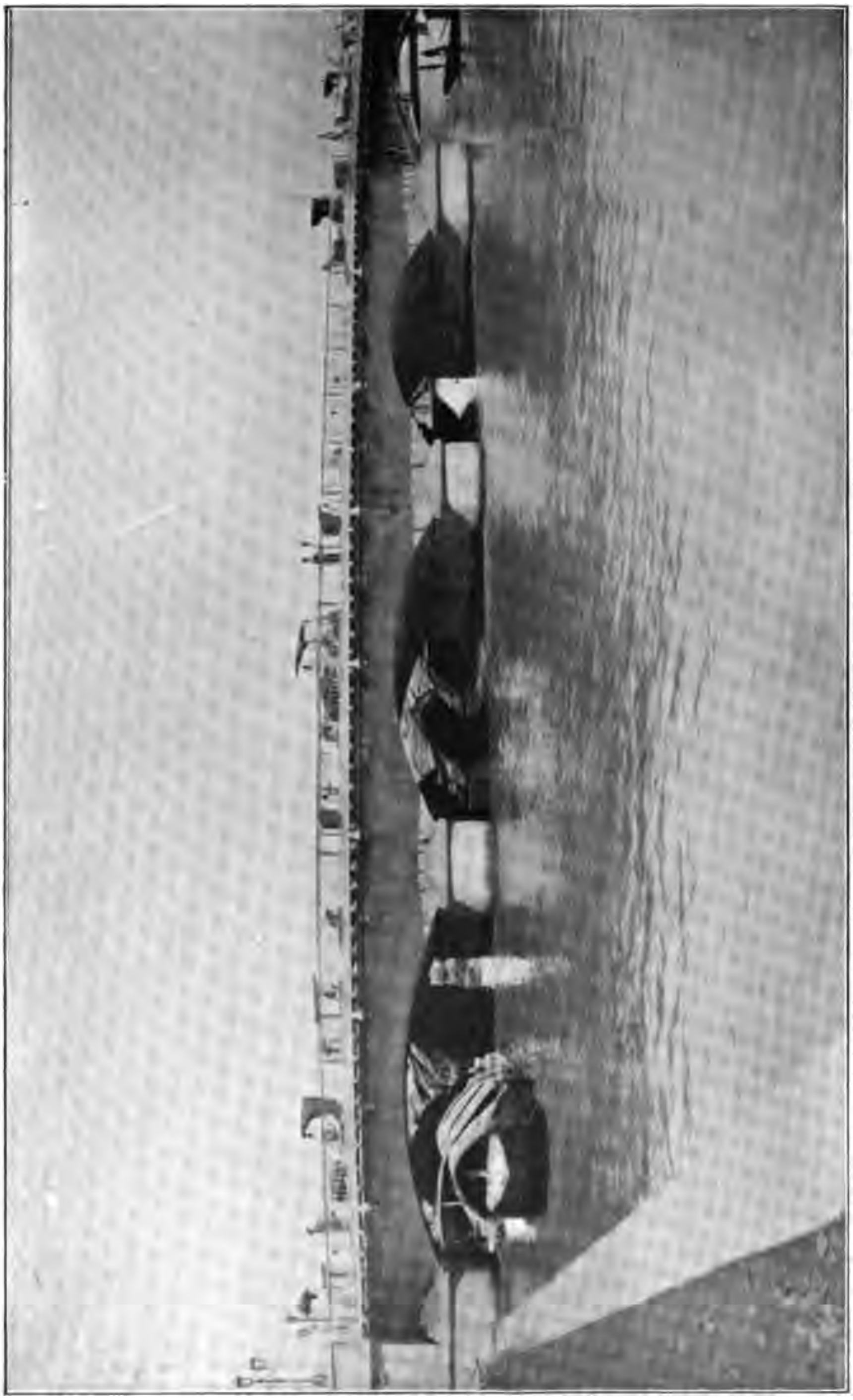


GRAND CANAL BRIDGE, CANTON, CHINA.

By courtesy of "Cassier's Magazine."



ANCIENT BRIDGE, DIZFUL, PERSIA.



BRIDGE OF SPAIN, MANILA.

JAPANESE STONE BRIDGES.

THE rapid progress of the Japanese in modern civilization, is too often remarked in many publications to need mention here, but when we come to learn of the really creditable and wonderful structures built by them hundreds of years ago, we are led to think that this progress is no more than was to be expected.

As remote as the year 1665, there was built in the Province of Etchin a cantilever bridge of timber, which in the light of modern science almost puts to shame our great steel cantilevers of the present day. As it is not a stone arch, it has no place among the illustrations, and only a brief description of it will be given. From each bank six slanting beams are cantilevered out, the shore ends being anchored down, and the outer end of each beam projecting out beyond the one below. In this way a distance from each bank is covered, so that a horizontal beam will reach across, and acting as the suspended span, close the crossing.

The banks around the bridge are protected by large boulders, enclosed and held in place by large nets of bamboo. So there are at this one place, examples of Japanese engineering of the "old school" of as striking a character as can possibly be found anywhere.

The bridge at Atsuta near Nagoya, is a representative of the more primitive type of the stone bridges of Japan. Rough abutments of rubble stone are laid upon each bank, while between are bents of stone. The caps support joists, which conform vertically to the curve of the bridge, and on these are laid slabs of stone to form the footway. The illustration shows all these details very plainly, and also the details of the very simple balustrade. One is surprised on comparing this with the cantilever bridge just described, at the small merit possessed by the stone structure and it really seems to be very clumsy.

Mito Garden at Tokio, however, has a bridge which is more nearly a modern stone bridge. The rise of the arch, which is of short span, is large proportionately and gives a bold effect. The spandrels are constructed with masonry in horizontal courses, and surmounted by a plain coping. The usual steps of the high Oriental bridges are the paving of the footway, and are flanked by parapet railings of really ornamental design. The posts have carved tops, while the openwork of the parapet is of Oriental scroll work. The steps are carried up the steepest parts of the sides of the bridge, and discontinued when a secure footing on the lighter grade over the crown of the arch is possible. This bridge is another example of the harmony existing between the curve of the arch ring and the curve of the coping, apparently approximating very closely the theoretical curve of the upper boundary of the spandrel filling, and one is led to wonder if it was not found out in an experimental way, as Edwards found it out in his Pont-y-Prydd Bridge, where after several trials the right weight of masonry was reached, so that this South Wales structure was stable.

The Spectacle Bridge or the Nishi O-tani at Kioto, which comes in logically at this place in our descriptions, is really the most notable stone bridge in the Orient, simply from the fact that it is of a different type of construction, so far as known, from any other bridge in the world, the two openings which give it its name, being complete circles. Whether or not the masonry was carried completely around and across the bottom for the purpose of paving the bottom it is impossible to say, but it suggests that where in any new structure this is necessary, a solution is possible which is of æsthetic value. Some other, and presumably later views, have a mass of lotus, with their big leaves and flowers hiding the lower part of the circle. It is well to note that the spandrels are neatly constructed and coped by a single layer of stone. The roadway is a vertical curve, presumably so without any necessity, but from custom. The balustrade is very neat, and of very good design; the lower half of each panel being very nearly solid and the upper half more open, while the posts are capped by an urn-like design, which is Oriental enough to please the most critical.

The bridges described are without exception those of ancient Japan, and when viewing those of the modern Japanese era they are seen to be essentially the same as those of the older civilized countries.

The Imperial Palace Bridge at Tokio is perhaps as elaborate a stone bridge as can be found anywhere in the Orient, and the surrounding buildings give a picturesqueness to the view which is as pleasing and certainly more finished than any similar view of the older bridges.

The piers are rectangular with a projecting belt course at the spring-line, above which counterforts are carried up straight with saxon groins on the corners.

The arch stones are cut to make each individual stone distinct, and the keystone is prominent by reason of its greater thickness and depth. The springing of the arch is hidden, a fault which has been frequently pointed out on structures in the Occident.

The spandrels are paneled similar to the Grosvenor Bridge, where a discussion of such inappropriate detail was gone into at length, although it can be said to be less objectionable in the present instance where the spans are not great. The balustrade is quite appropriate with its turned balusters to give it finish. While there is nothing about the structure worth special study, it is of value owing to the promise it gives of what may be expected in masonry structures in the Orient during the twentieth century.

CHINESE STONE BRIDGES.

RESEARCHES in the Orient make it almost certain that, to the early inhabitants of this part of the world, we are indebted for the principle of the stone arch. Prof. Malverd A. Howe in his "History of the Stone Arch" cites the discovery of a Bablyonian arch of mud brick, at Nippur, which was probably constructed about 4,000 B. C. He further says: "There are a large number of examples of the true arch in bridge construction in China, as well as the primitive form of stone bridges without arches. The date at which these bridges were constructed is unknown, but many believe that the Chinese built the true arch long before it was known to the Western world.

"There is an account of a bridge over a river named Laffranyi, China, connecting two mountains. The bridge is said to be of one arch of stone, having a span of 600 feet and a height of 750 feet (Edinburgh Encyclopedia). The authority for this account is not authentic, and although a stone bridge of such magnitude is not impossible from the engineer's point of view, it is yet improbable.

"The old voussoired arch bridges of the Chinese are interesting from a peculiarity of the arch ring. Each stone from 5 to 10 feet in length is cut so as to form the segment of the arch, and in such cases there is no keystone; ribs of wood fitted to the convexity of the arch are bolted through the stones by iron bars fixed into the solid part of the bridge; sometimes they are without wood, and the curved stones are mortised into long transverse blocks of stone.

"The details of the more modern Chinese arches do not differ essentially from those employed in other countries."

The marble bridge, in the Summer Palace Gardens at Pekin, is a beautiful bridge of seventeen arch spans, leading to an island in the lake. The spans, however, are short, but the bridge rises higher at the center, as is characteristic of nearly all Chinese bridges.

This is shown in the illustration of the three span stone bridge near Shanghai. The piers and abutments are of the crudest design and construction, but the arch ring has some pretension to beauty. The parapet, while of rough construction, is in panels and has ornamental finish at the ends. The steps over the arches tell the story of the absence of vehicle traffic. With all the lack of real design or finish, there is a picturesqueness about the structure which might be copied to advantage in some park bridges. This is due in great measure to the bridge rising higher at the center, as is true of probably a majority of those in the Orient, and is not to be found so accentuated anywhere else except in the bridge of Venice. Many Chinese bridges are more striking in this regard, such as the one over the Grand Canal at Canton, it being the purpose here to allow of the passage of boats underneath as at Venice. This bridge is plain, but of neater construction than the one near Shanghai.

The Camel-back bridge in the Summer Palace Gardens at Pekin is probably the most beautiful single span bridge of this type in existence. It is famed in Chinese nursery rhyme, as other famous bridges are in the songs of other lands.

"If you chance to be crossing the Camel-back bridge,
Each step leads you up till you come to the ridge;
The lantern grass floats on the pond like a sail;
The silver fish bite at the gold fish's tail;
The big bellied frog sitting there on the rock
Keeps endlessly calling 'wahwa, wahwa!' "

The general design of this bridge, however, is fine, as the almost Gothic outline of the intrados is in perfect harmony with the curves of the parapet. The parapet rail or balustrade is simple, yet pleasing, and fortunately a panel instead of a post is placed directly over the keystone. It is not overstating the case to say that there is no bridge, whatever its size, more striking in general appearance.

The effect of many Oriental bridges is greatly enhanced by the architectural surroundings, as exemplified by the pagodas in the Shanghai and Canton views—the architectural framework in which the bridges are set.

A recent article on the "Development of China" contains the following remarks on Chinese engineering works in general.

"There are some sinologues who are disposed to maintain that the Chinese, in one way or another, have anticipated most of our important modern inventions." While this is certainly not true there can be no doubt that for many hundreds of years they have been familiar with a few arts and sciences that we are disposed to regard as purely modern.

Some of the ancient Chinese work of engineering character shows that they possess a high degree of skill at an early stage in their history. Take, for example, the stone arch bridges found here and there throughout China; some of these arches are very old, and all of them exhibit a symmetry and gracefulness obtainable only with a high degree of skill. Then, too, the cantilever principle of bridge construction has long been known to China. We have an excellent type of this kind, which is described by Parsons as follows:

"This bridge consisted of six spans, with a length of 480 feet and width of 20 feet, paved with cobble stones, while over it is erected a frame to carry awning mats in summer. The substructure is masonry piers, in good condition, but evidently of great age, while the superstructure is of wood and a genuine cantilever in design. The timbers which compose it are about 10 inches square, laid in alternate layers in the direction of, and across the line of the bridge. Each longitudinal layer projects beyond the next one below, and the series of such projections builds out the cantilever arms until the opposite ones are near enough together to be spannd by a single timber. The superstructure is not so old as the substructure, the timber having been undoubtedly replaced, possibly many times."

PERSIAN STONE ARCHES.

MENTION has been made of the nearly Gothic outline of the camel-back bridge in China, and as it seems almost certain that to Asia we are indebted for the principle of the arch, it is possible to go a step farther and in studying the stone arch bridges of Persia to say with a great deal of certainty that to Asia, and to Persia in particular, we are indebted for the Gothic arch.

There can be cited the bridge Allah Verdi Khan, the main spans of which are flat Gothic arches of nearly 19 feet in the clear, while the second tier of small arches above the main spans are of the same outline, but only about half as large. The two tiers give the structure very much of a "Gothic Cathedral" appearance. The Mianch Bridge is another one with arches of very similar design, but a structure of only one story. From a French authority we have an account of the "Pont de le Fille" with a main span of about 75 feet; the approach spans being of Gothic outline, while the piers have counterforts pointed at the top adding much to the general Gothic effect.

Two hundred and fifty miles southwest of Ispaham is the decayed city of Shuster, which recalls the ancient grandeur of the country, the city having its protecting citadel for the 5,500 people. The River Karun, on which it is situated, is crossed by a stone bridge of many short spans. The river is very swift, as it is near the hill, and the piers have been built in the rapids where the rock was most exposed, so that the bridge is of very irregular serpentine plan. The arches are of the Gothic form and very ancient, although the age of the structure is unknown.

Dizful, on the River Riz, in the Province of Khuzistan, and about 180 miles west of Ispahan, is the location of the bridge illustrated. There are twenty arches, three of which are shown. The piers are formed of rubble masonry with great spreading bases, and are nearly as thick as the span of the arches. The spandrels over the piers are lightened by the small arches, and add to the architectural effect, if such a rough structure can be said to be an architectural creation. Dizful is also noted for its nearly two score sacred tombs and nearly as many mosques. The ruins of ancient Susa are only a short distance away.

MANILA STONE BRIDGES

WHILE not bridges of the Orient in the sense usually meant, the bridges of Manila are nevertheless situated in that part of the world called Oriental.

There are, so far as is known to the writer, no stone bridges of any consequences in the Philippine Islands that were constructed by the natives, but they are such as have been constructed under the Spaniards.

The old stone bridge across the Pasig River which has been partly destroyed by earthquakes, and which has been patched up with timber, is doubtless familiar to most engineers as having been pictured so many times in the magazines during recent years. While not of the type of the structure under discussion, it may not be amiss to mention the suspension bridge over the Pasig, with stone towers, which has also been illustrated very often.

When, however, we come to speak of stone bridges of any considerable size, there is but one example of any prominence—the Bridge of Spain. It is a structure of eight spans, three of which are braced arches.

The stone spans, three of which are shown in the illustration, are of exceedingly neat design. While of very slight rise, the thickness of the arch ring is in keeping, and the piers are of sufficient thickness to indicate a good design from a theoretical standpoint and to be pleasing to the eye of the engineer. The piers have rounded ends and are neatly capped, the projection of the caps being such as to give the entire structure a finished appearance.

When it became necessary to widen the structure, steel beams were placed crosswise of the roadway, projecting out as far as it was desired to increase the width on each side.

The appearance is much more pleasing than could be expected from so incongrous an arrangement, and it is certainly to be hoped that the government will replace the work with concrete or stone work more in keeping with the arches.

The open railing on the spans, joining the masonry parapets on the abutments, is really in harmony with the other portions of the structure and could not be replaced to the improvement of the general appearance of the bridge, unless the method of widening the roadway should be changed to masonry construction as mentioned.

ENGINEERING STUDIES

PART VII.

CONCRETE--STEEL ARCH BRIDGES

By CHARLES EVAN FOWLER, M. Am. Soc. C. E.

> *"Whoever thinks a faultless piece to see,*
> *Thinks what ne'er was, nor is, nor e'er shall be."*
>
> * * * * * *
>
> *"Content if hence th' unlearn'd their wants may view,*
> *The learn'd reflect on what before they knew."*
>
> —POPE

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1907

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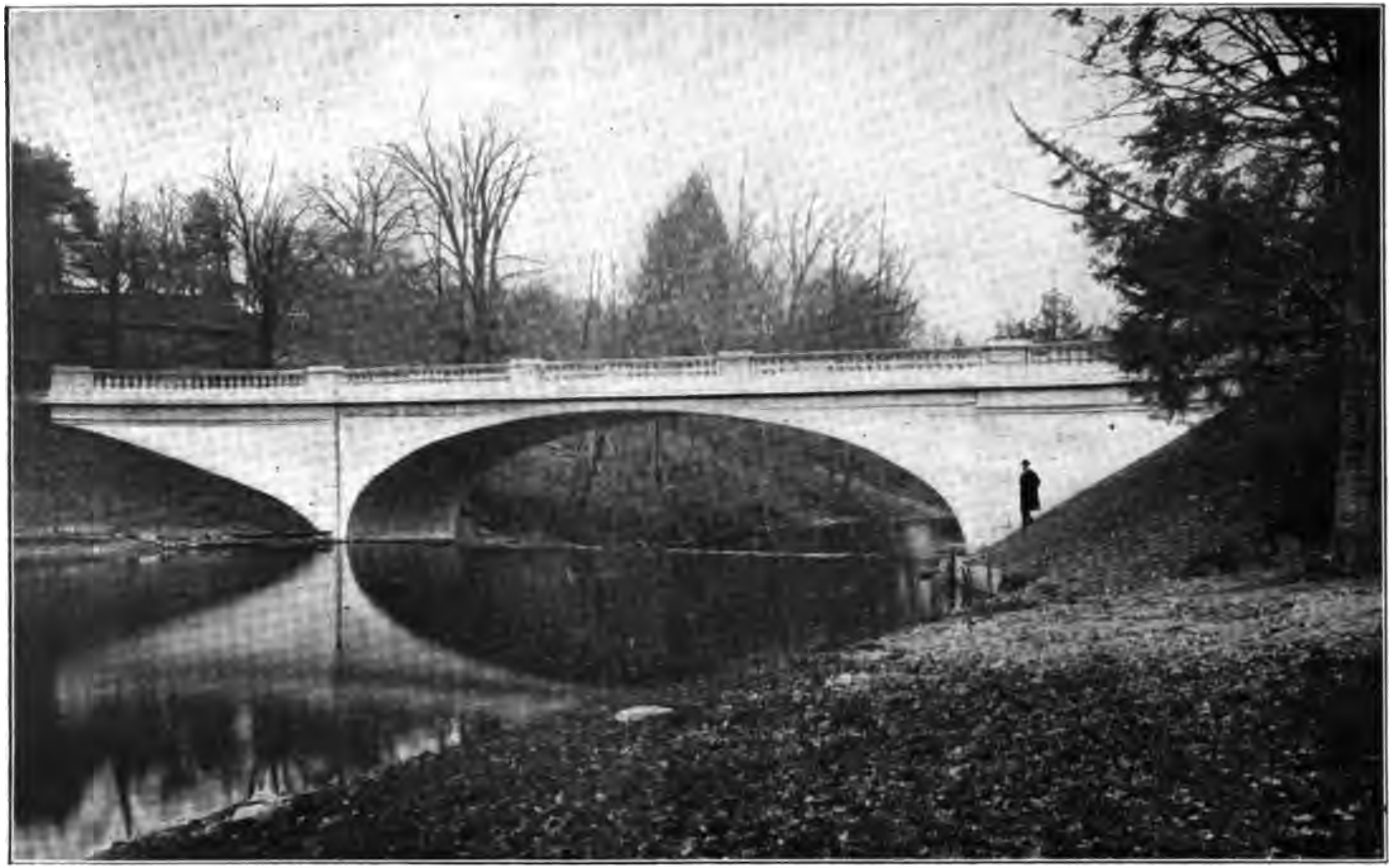
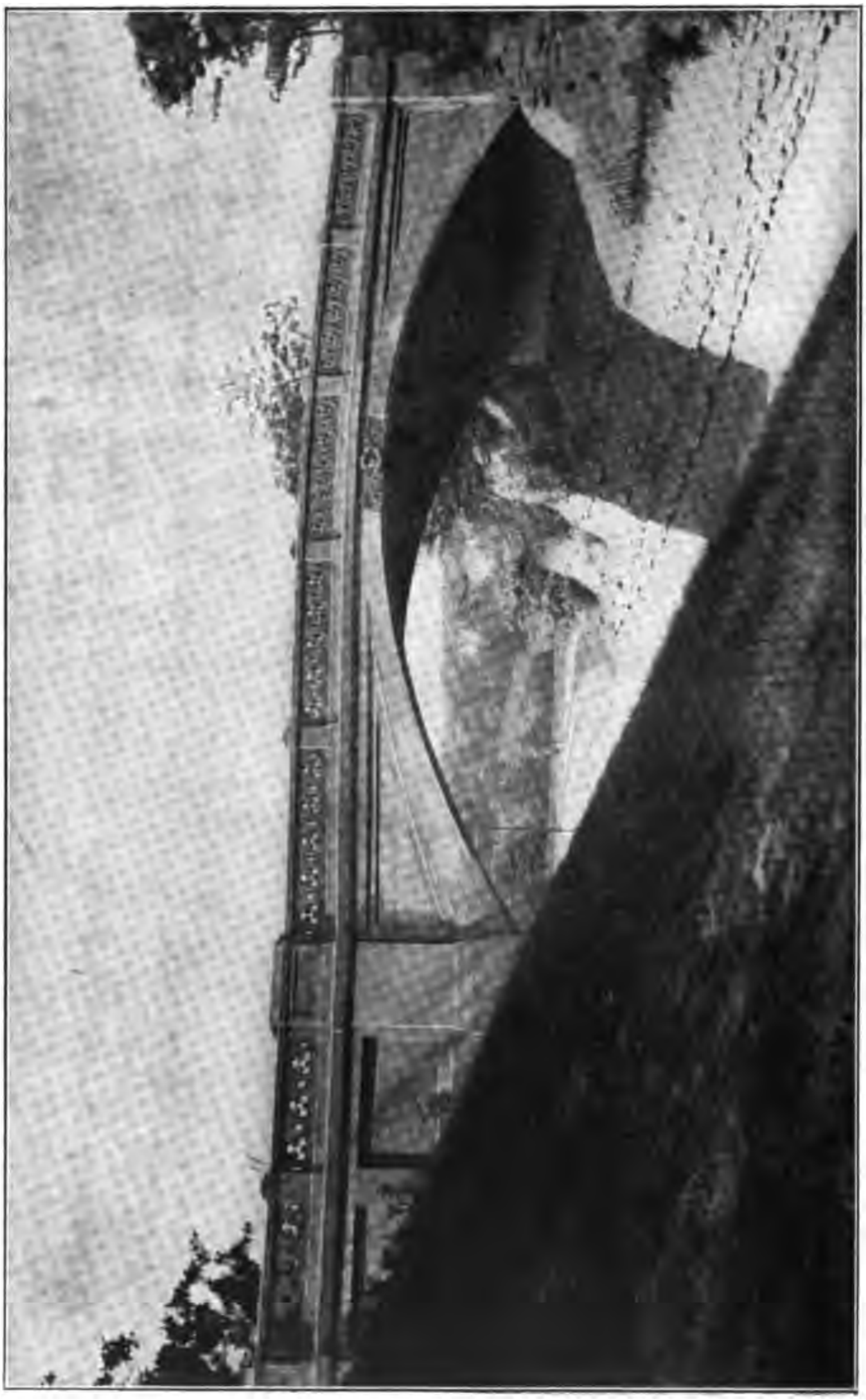
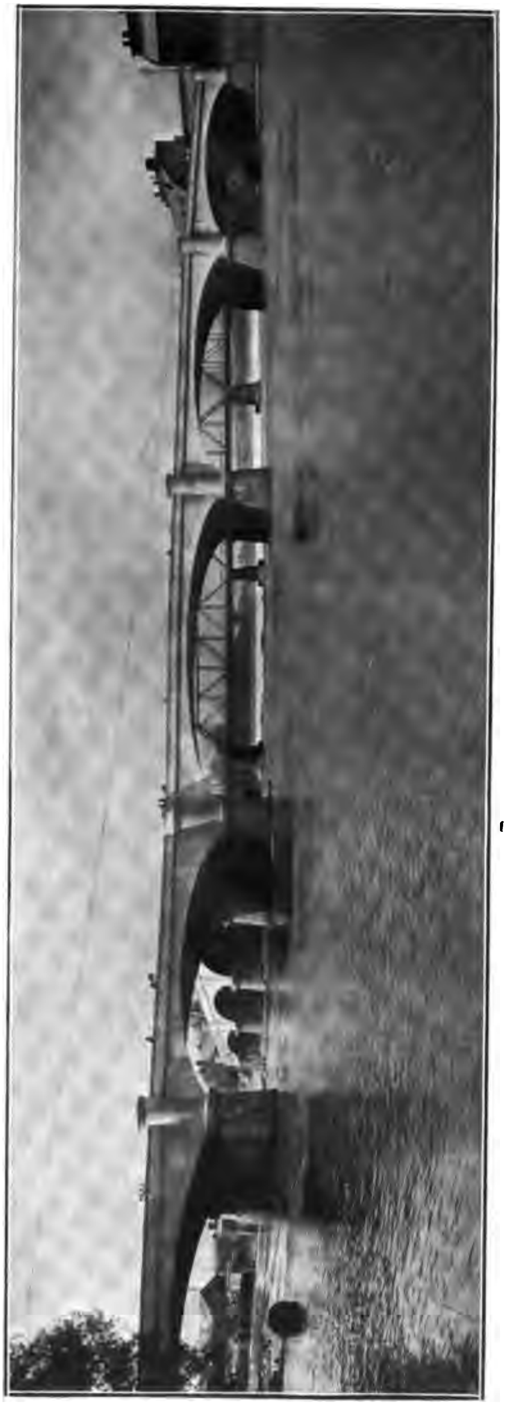
BY CHARLES EVAN FOWLER



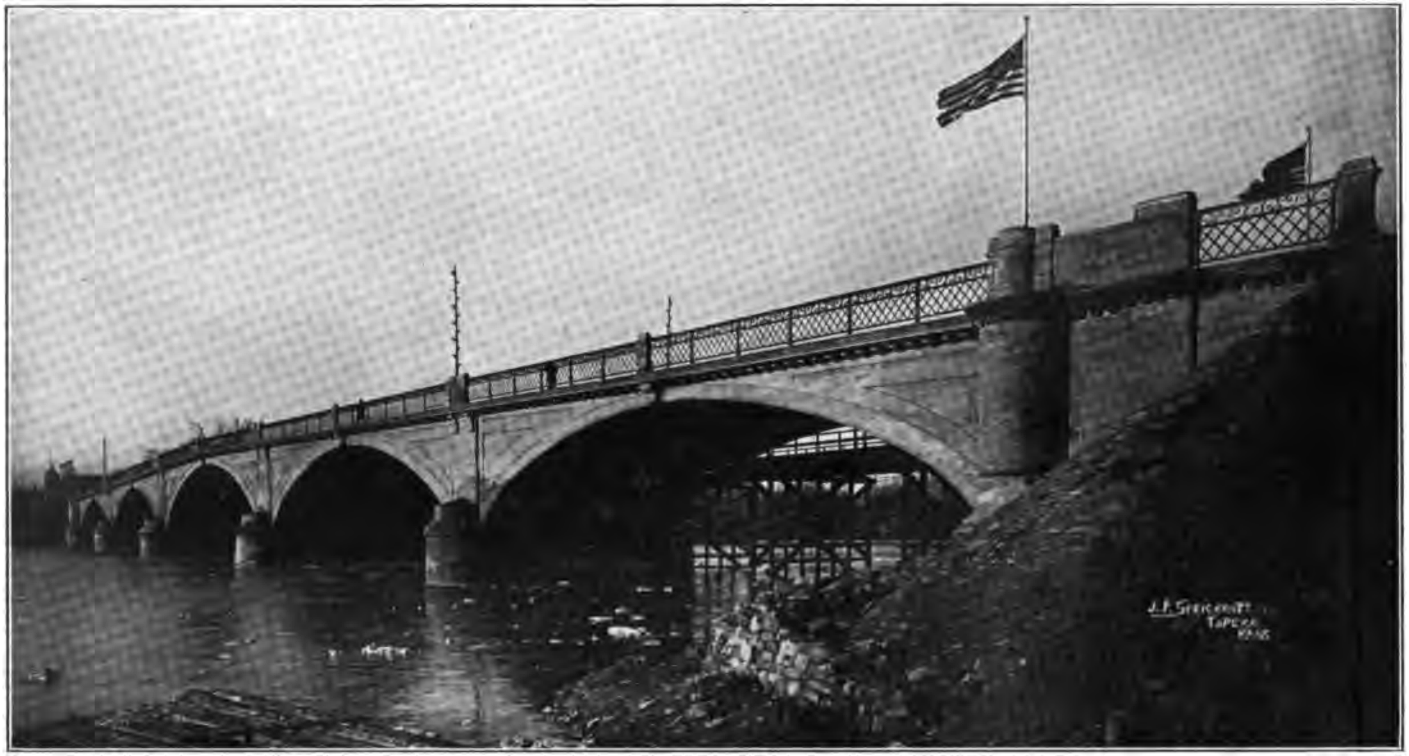
VANDERBILT ESTATE, HYDE-PARK-ON-HUDSON.



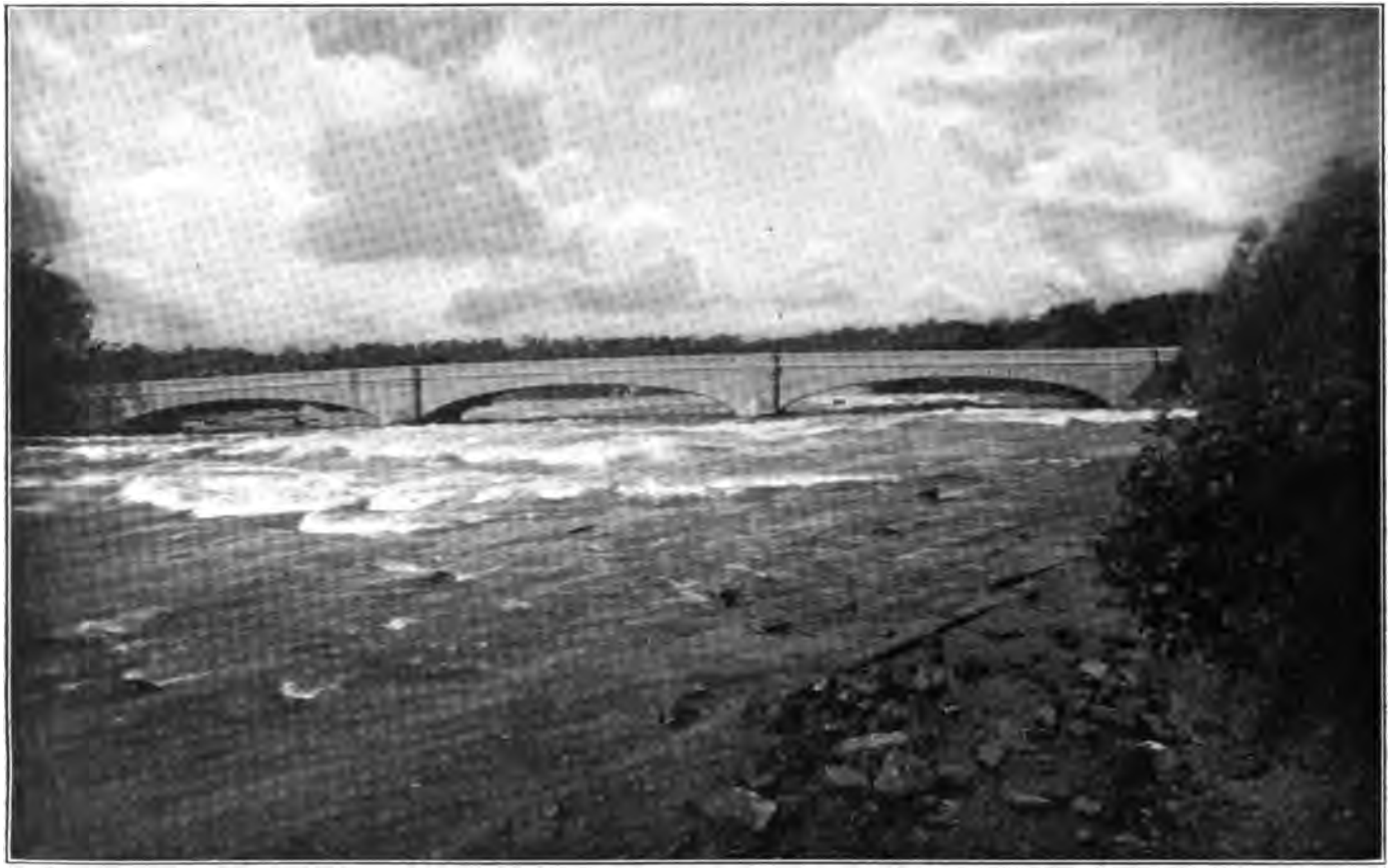
EDEN PARK, CINCINNATI.



ZANESVILLE, OHIO.



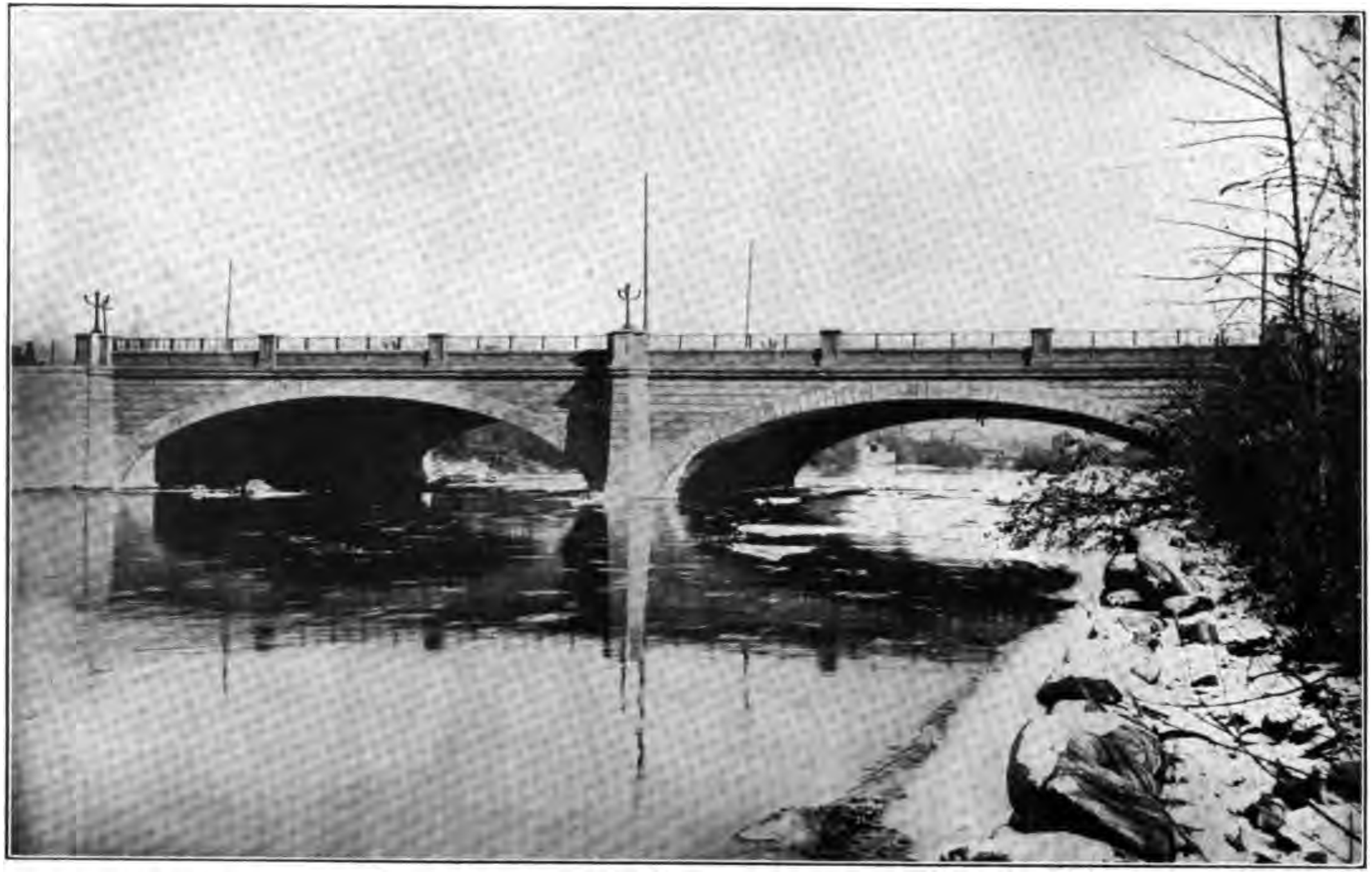
TOPEKA, KANSAS



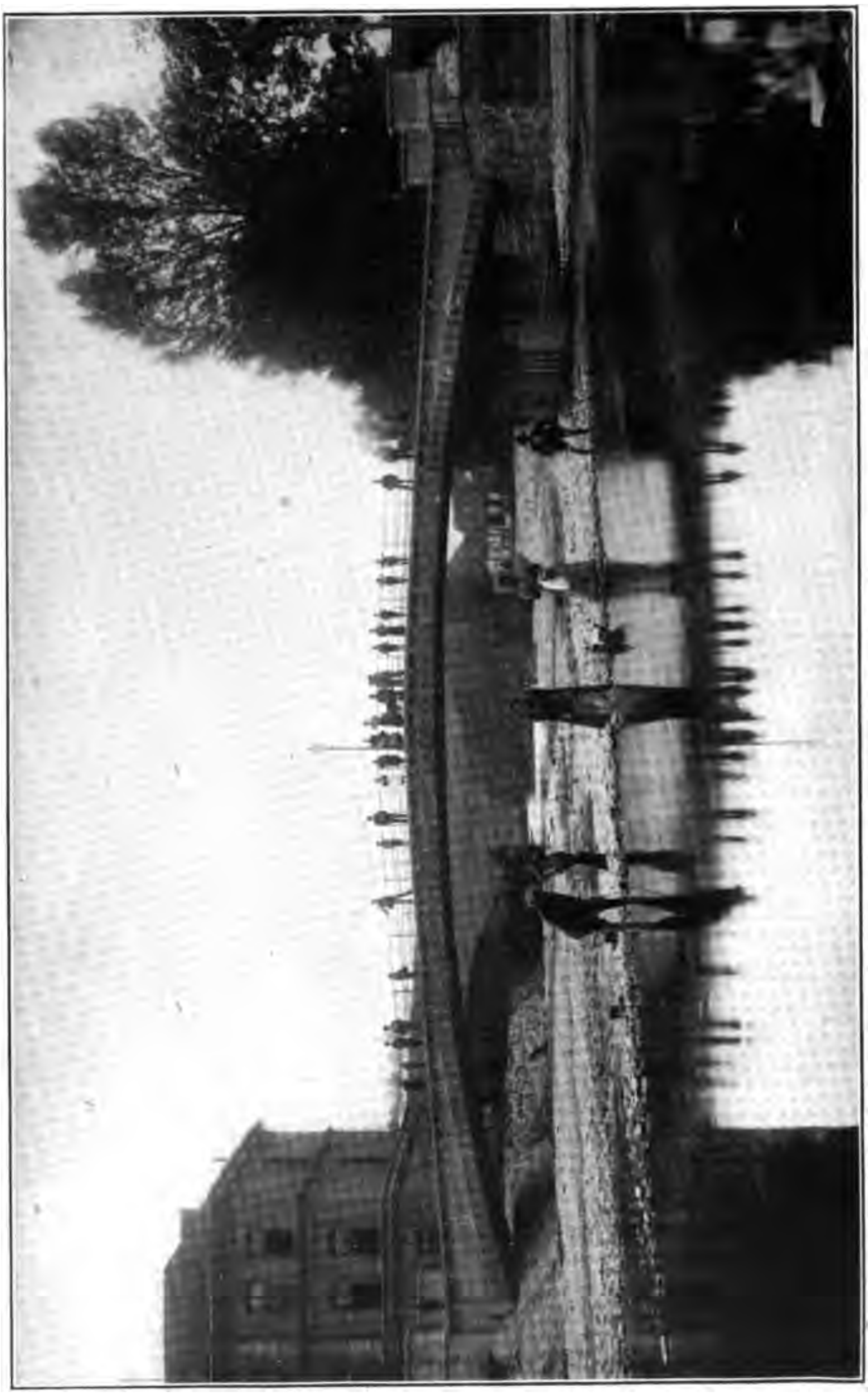
NIAGARA, ABOVE THE FALLS.

FOREST PARK, ST. LOUIS.

PATERSON, NEW JERSEY.



RENO, NEVADA.



STEYER, AUSTRIA.

CONCRETE-STEEL ARCH BRIDGES.

THE rapid development of concrete-steel construction has led to the building of bridges of this type in every section of the United States. It is to be deplored that so many have been built of such very light sections; too much dependence being placed, apparently, upon theoretical considerations, and not enough attention having been paid to the practical.

The bids at a recent letting for a large concrete-steel bridge varied by one hundred per cent., indicating that some of the bidders had a very much greater confidence in the theory, and perhaps in the materials to be used, than had others.

The slight depth necessary for the arch-ring at the crown is very often a great advantage, when the clearance between water-line and floor-level is small, but there is danger, from the architectural standpoint, of getting the proportions so attenuated as to spoil the artistic effect.

The readiness with which concrete lends itself to being molded into artistic forms, provides a great temptation for the engineer or architect designing a concrete bridge to use frivolous details and too much ornamentation, thus spoiling many structures which would, if plainly designed, be very creditable. Many small and medium-sized bridges are simply bad copies of notable stone arches, the details of which were appropriate enough in their places, but entirely unsuitable for the smaller structures. It must, therefore, be considered better, from the esthetic viewpoint, to design a plain and wholesome structure than to make a bad copy.

Let the engineer be humble enough to consult a good architect when designing a notable masonry bridge, unless he is perfectly sure of his plan being entirely fit. But better leave it as designed by a good engineer than to run the risk of having it spoiled by calling in a poor or mediocre architect.

VANDERBILT ESTATE, HYDE-PARK-ON-HUDSON.

THE bridge on the estate of F. W. Vanderbilt, at Hyde-Park-on-Hudson, has been chosen for one of the illustrations in this part, as being one of the most chaste designs that has been made for a concrete bridge. The span is small, being 75 feet in the clear, while the rise is 14 feet 8 inches, and the roadway 16 feet. The depth of the arch-ring is but 15 inches, and has led to the most serious fault in the design—that of making the depth too slight from the intrados to the top of the coping. The paneling of the spandrel-walls, while it would be out of place on a large bridge, is appropriate enough for a small one. The relief afforded to the arch by setting out the side-walls of the abutments is very pleasing, and the joggled work at the offset is in entire harmony with the design. The balustrade with turned balusters is very neat and accords well with the design. The base of the balustrade and of the posts was molded in place, but the balusters and top-rail were cast in forms and afterwards set in place.

The bridge is built on the Melan system, being reinforced with seven 9-inch steel I-beams.

The concrete for the arch-ring was composed of 1 part of cement, 2 of sand, and 4 of broken stone; while for the wing-walls, abutments, and spandrel-walls a concrete of 1 part cement, 3 of sand, and 6 of broken stone was used.

EDEN PARK, CINCINNATI.

AN art center like Cincinnati, Ohio, would naturally be expected to supply a notable example of an artistic masonry bridge, and the one illustrated, in Eden Park, is certainly a very beautiful structure. The arch-ring is neatly accentuated by the moldings, the ornamented keystone, and still further by the paneled spandrel-walls.

The abutments are well-designed and well-proportioned, being allowed to project enough to give the impression of the substantial abutments required to take up the thrust of such a flat arch. The paneling of the wing-walls is the most inappropriate part of the design, as the dying away of the panels in the ground is in bad taste.

The highly ornate design of the balustrade is very pleasing for a purely ornamental structure, and the details are exceedingly well-proportioned.

The span of the arch is 70 feet, the rise 10 feet, and the total width of the bridge 32.5 feet. The roadway is 18 feet in width and the sidewalks 5 feet each. The arch is 15 inches thick at the crown and 48 inches at the spring, reinforced with 9-inch 21-tb. I-beams, spaced 36 inches apart.

ZANESVILLE "Y" BRIDGE.

ONE of the most unique bridges in the world is the "Y" bridge at Zanesville, Ohio. It was built to take the place of a wooden bridge of the same plan, at the confluence of the Licking and Muskingum rivers.

The bridge is of good design, being a plain, massive, monolithic structure, well suited to the location. The piers are of plain design, with rounded ends, and coped with a single course.

The elliptical arches are perfectly plain, as are also the spandrel-walls and the balustrade. The structure is relieved by the semicircular counterforts over each pier, which are carried up above the balustrade, to relieve that as well.

The design, while such as might have been made in medieval times, is very harmonious, and the bridge one of the most pleasing that has been built of concrete.

The spans in the long arm of the bridge are all 122 feet in length, the first having a rise of 11.5 feet and the others of 14.6 feet. The arm with two spans has one span of 120.6 feet with a rise of 11.5 feet, and one span of 99 feet with a rise of 6.28 feet, The spans in the other arm are all 81 feet, with rises of 14.6 feet, 10.85 feet and 6.06 feet, respectively.

The thicknesses of the arch-rings vary from 18 inches for the shortest span to 30 inches for the longest. Each span is reinforced with 15 pairs of steel bars of the Thacher type, ¾-inch in thickness and varying in width from 3 to 5 inches, the bars being placed 2 inches from the top and bottom of the arch-ring and 36 inches apart transversely. The concrete for the arch-ring was composed of 1 part cement, 2 parts of sand and 4 of stone. The entire structure was carefully built under a detailed specification, and is one of the best examples that has been carried out.

TOPEKA, KANSAS.

THE largest, at the time it was built, and one of the first concrete-steel bridges to be constructed in the United States was that at Topeka, Kansas, over the Kansas River. There are five spans, the central one being 125 feet in length, the two adjoining ones 110 feet each, and the shore-spans 97 feet 6 inches each. The roadway is 26 feet wide and the sidewalks 7 feet each.

The piers are comparatively plain and of very neat design. The arch-rings are well defined, but the spandrel-walls would have been much more pleasing if left plain, than with the inappropriate paneling that was used. The counterforts over the piers relieve to some extent the flatness of the face of the structure, but would have been better if more prominent, as are those over the abutments. The brackets and consoles supporting the coping are appropriate, but a plain balustrade would have been much better than the iron railing, which detracts much from the effect of solidity which the structure should have. At any rate, the solid masonry balustrade should have been carried to the end of the wing-walls.

There may possibly have been some reason for the broken grade line, but the effort should be made in every masonry bridge to make the grade line a gentle curve. The general appearance would have been improved by lamp clusters over the piers and abutments, which were originally arranged for, but which were omitted when the bridge was built.

The general arrangement of the bridge, its division into five spans, and its general proportions are good; but it will always be wise for the designer to take care that an otherwise good design is not marred by the omission of some vital features and by the use of inharmonious details.

NIAGARA FALLS.

THE location of this bridge between the mainland and the island above the falls, is an ideal one for a concrete or masonry bridge. The structure consists of three spans—one of 110 feet and two of 103.5 feet—and is built on the Thacher patent concrete-steel system.

The engineer can profitably take some time to study the bridges at Niagara, both above and below the falls. The graceful steel arches of long span are especially appropriate for spanning the gorge, adding to the grandeur and impressiveness of the scenery, while the masonry bridge illustrated is in entire harmony with the low banks and the inert force of the waters before they leap over the falls into the gorge. In perfect harmony, too, are the rock facing, the thick piers, and the solid balustrade.

FOREST PARK, ST. LOUIS.

THE concrete-steel bridge in Forest Park, at St. Louis, is another example of the fitness of this type for the ornamental structures required in parks.

The span is only 60 feet, the rise 15.5 feet, and the thickness of the arch-ring 11 inches at the crown. The arch is built on the Melan system, with eleven 8-inch steel beams as reinforcement for the 32 feet width of the bridge, the roadway being 24 feet and one sidewalk 6 feet in width.

The abutments are made of concrete with 1 part cement, 3 of sand, and 6 of broken stone; the spandrel- and wing-walls of 1-2½-5 concrete, and the arch-ring of 1-2½-4 concrete.

The intrados of the arch is tastefully molded, and the spandrels and abutments are paneled.

The design is somewhat marred by the two molded rings in the spandrels and by the heavy balustrade post, which is bracketed out at the center.

Here again is an example of where the roadway and balustrade should have been on a gentle curve from end to end of the bridge. The balustrade itself is of very good design and in harmony with the bridge.

PASSAIC RIVER, PATERSON.

THE employment of stone facings for a concrete-steel bridge is shown in the bridge over the Passaic River, at West Street, Paterson, N. J. The following description is taken from "Engineering News":

"The bridge consists of three arches of nearly equal length on the center line of the bridge. The center span being 89 feet in the clear, and the two end spans about 88.25 feet in the clear. The rise of each of the arches is 9.5 feet. The two piers are at right angles to the center line of the bridge. With a width of 50 feet 10 inches on the soffit of the arches, the coping is carried out to give a total width of 54 feet, or 52 feet in the clear between the railings. At the ends of the bridge the roadway grade is at an elevation of 22 feet above datum, rising by easy grade to 25.5 feet at the center.

The concrete of the arch-rings is 15 inches in thickness at the crown, gradually increasing to 66 inches at the skewbacks, and embedding 10-inch I-beams weighing 25 pounds per foot, spaced 3 feet apart center to center. Expansion-joints are built in the spandrel-walls over the piers to provide for thermal changes. The space between the spandrel-walls is drained by 3-inch iron pipes built into the piers and abutments, and extending about 6 inches beyond the face of the latter. The entire face of the spandrel-walls and arches is finished with ashlar masonry of New Jersey brownstone, bonded into the concrete backing."

Inasmuch as a stone arch would not have been constructed with so small a rise, it is hardly to be said that the use of the sham stone facings is defensible.

The general design of the bridge is very good, but the slight depth of the bridge at the center, made necessary on account of the high-water elevation, and the use of an iron railing detract very much from the appearance of the structure.

RENO, NEVADA.

THE bridge at Reno, Nevada, is of very harmonious design, and, although consisting of two spans of only 65 feet each, is worthy of illustration.

The curve of the intrados is very graceful and suited to give plenty of waterway. The arch-ring has more depth than is usual in a concrete-steel arch, and the outlining of the arch-ring and arch-stones adds greatly to the appearance of the structure.

The curving of the batter lines of the piers is very good, and the solid base used for the parapet railing excuses, in large measure, the use of the metal railing on the upper portion. The lamp clusters over the piers and abutments add enough to the architectural effect to well repay the slight additional cost.

The bridge is constructed by using the Johnson corrugated reinforcing bars, spaced to conform to the stresses in the various portions of the bridge.

STEYER, AUSTRIA.

THE system of concrete-steel construction is peculiarly adapted to long spans with very little rise, and the bridge at Steyer, Austria, is shown simply as an example of the extreme to which the method can be carried.

The arch is built on the Melan system, with a span of 138.4 feet, a rise of 9.4 feet, and thicknesses of 2 feet and 2.3 feet at the crown and springing, respectively.

The arch-ring is made prominent by being blocked off to represent ring stones, while the remainder of the structure is of very indifferent design. In a few words, the bridge is an example of what can be done, and what not to do.

ENGINEERING STUDIES

PART VIII

BRIDGE APPROACHES

By CHARLES EVAN FOWLER, M. Am. Soc. C. E.

"Whoever thinks a faultless piece to see,
Thinks what ne'er was, nor is, nor e'er shall be."

* * * * * *

"Content if hence th' unlearn'd their wants may view,
The learn'd reflect on what before they knew."
—POPE.

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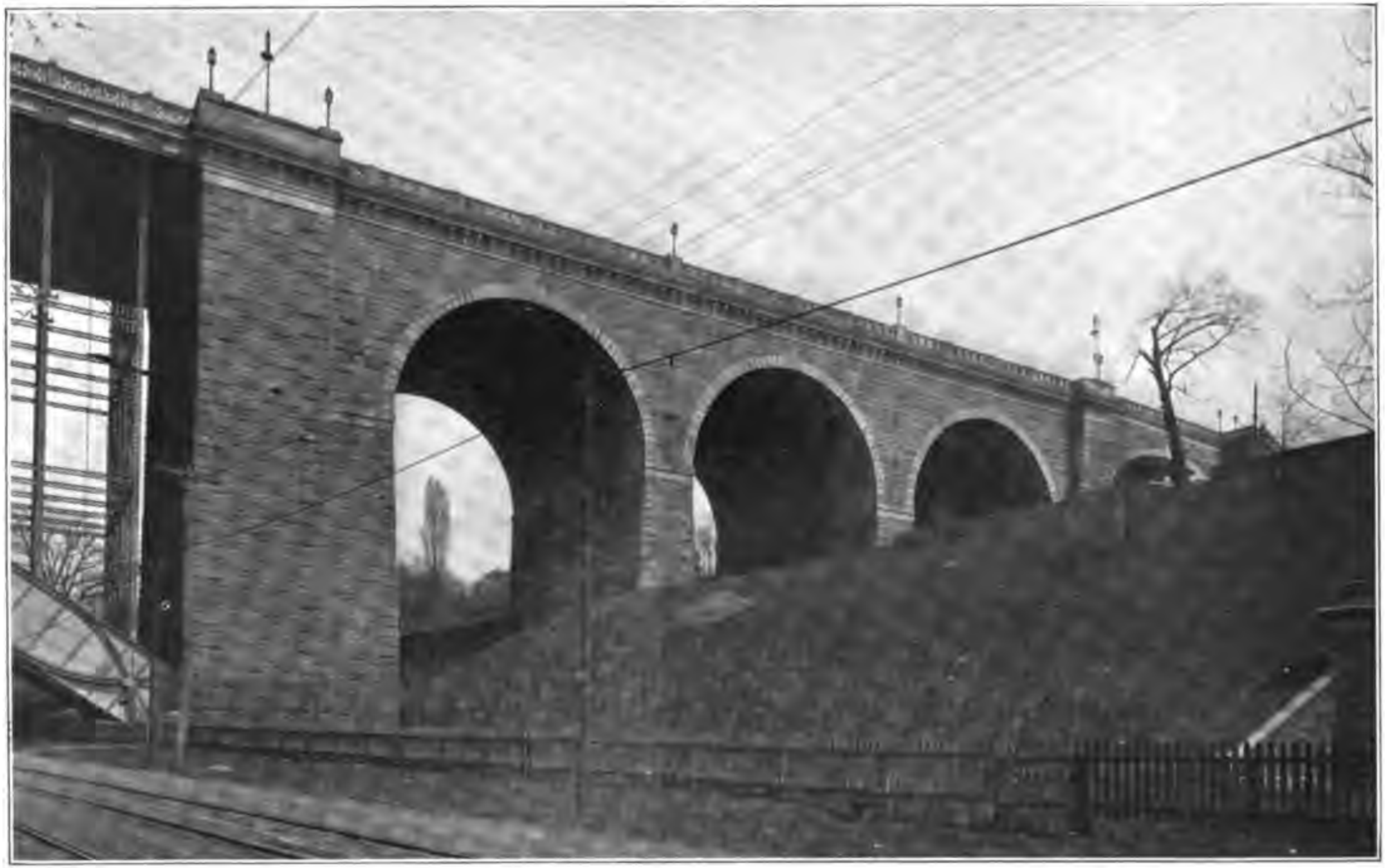
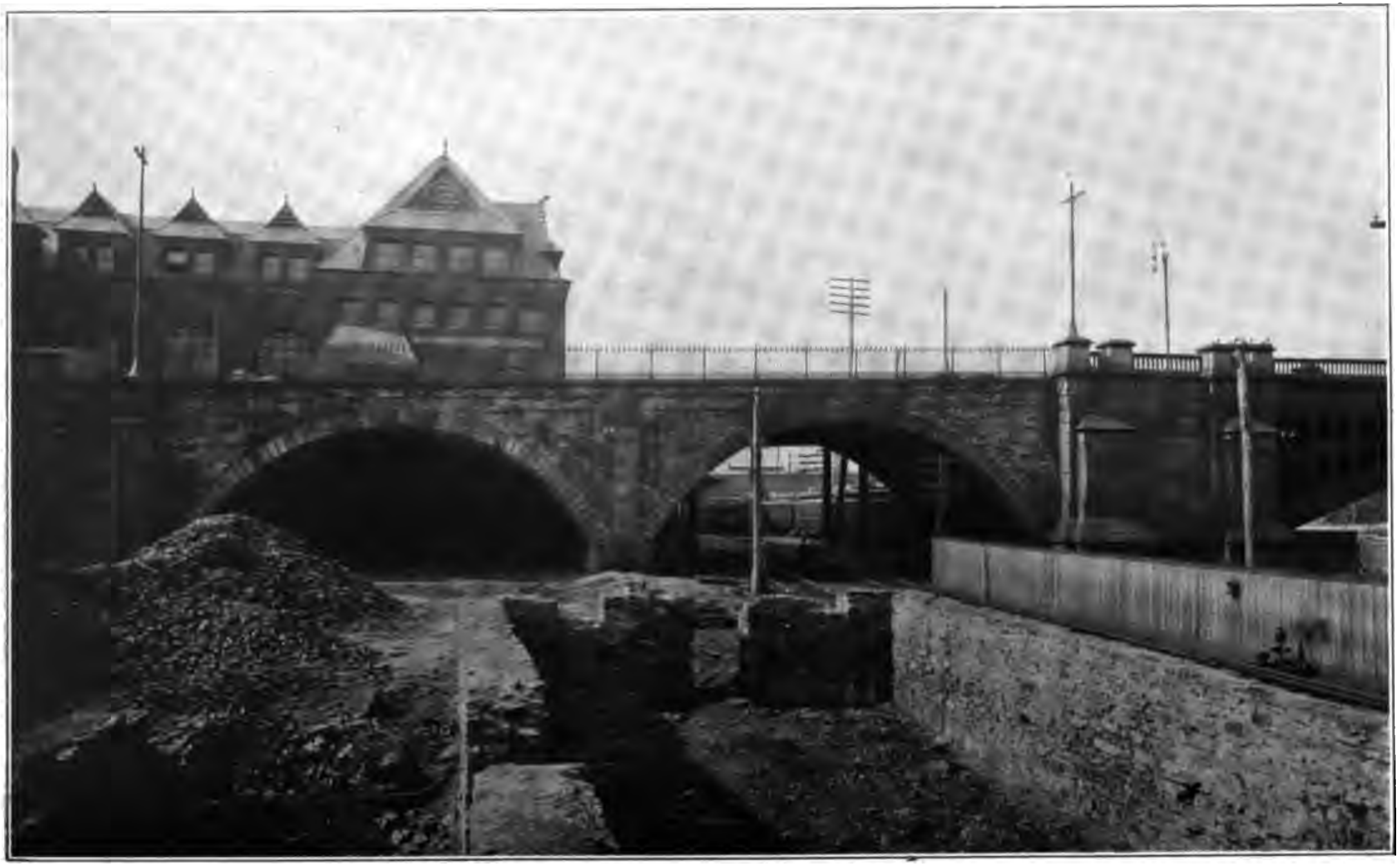


WASHINGTON BRIDGE, NEW YORK CITY.



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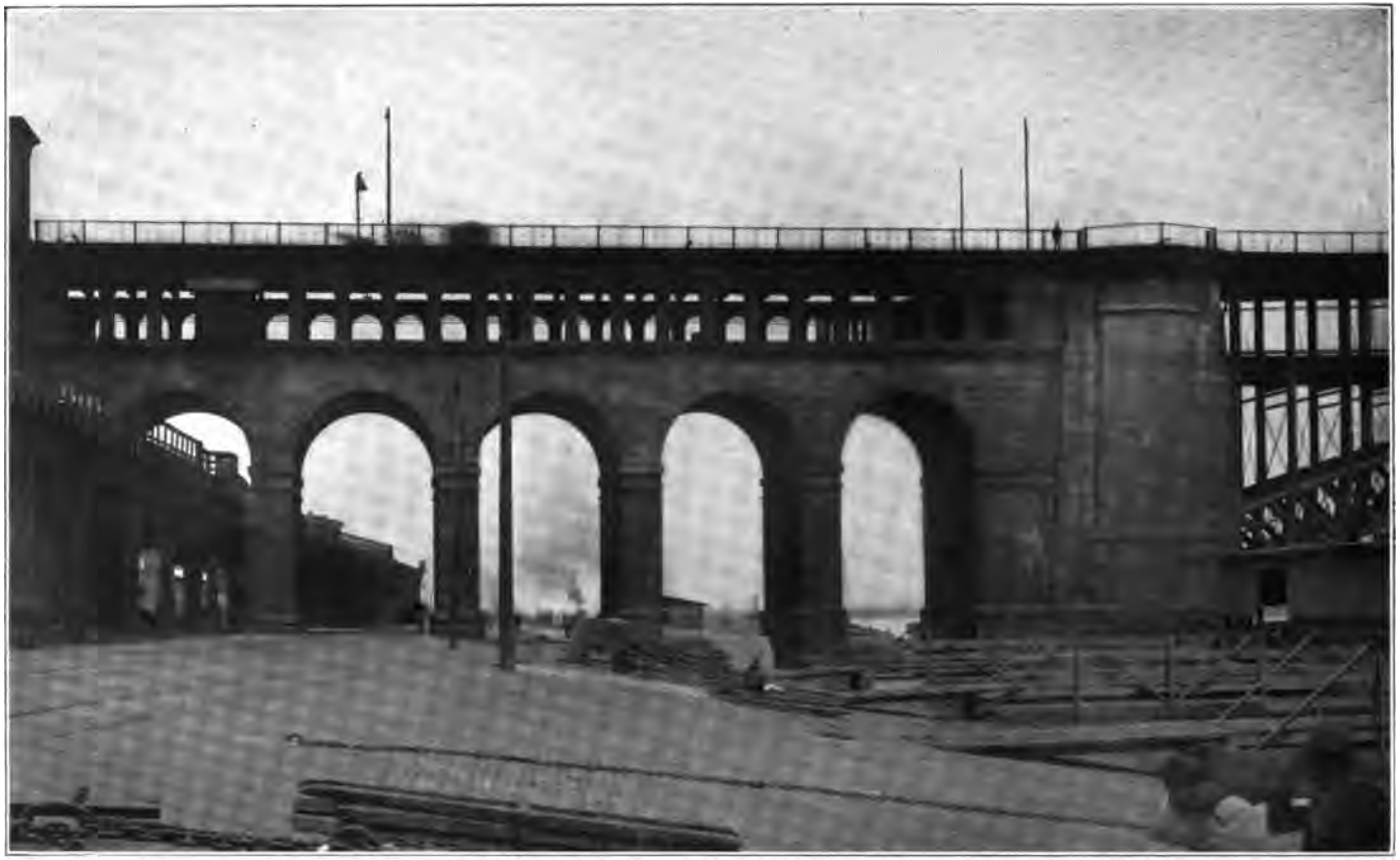

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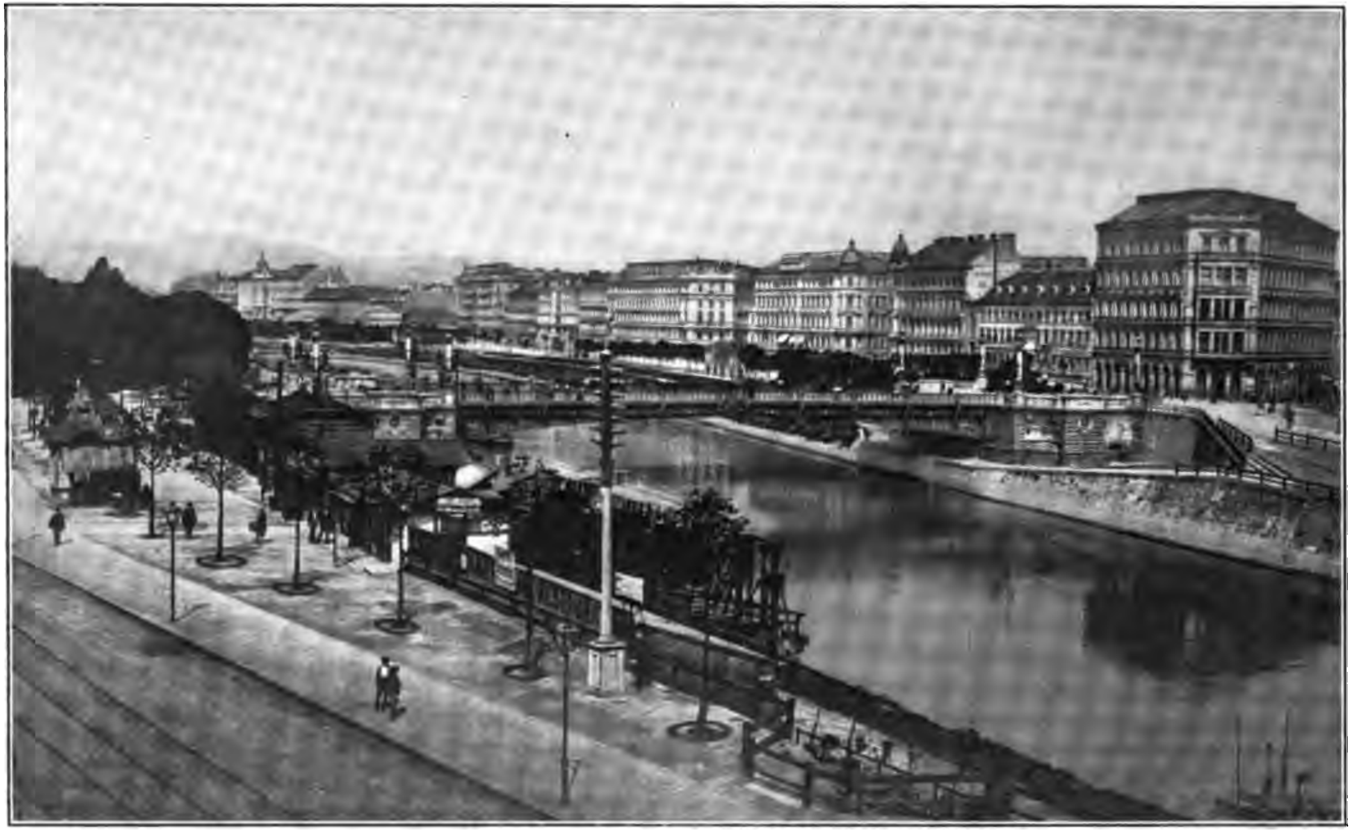
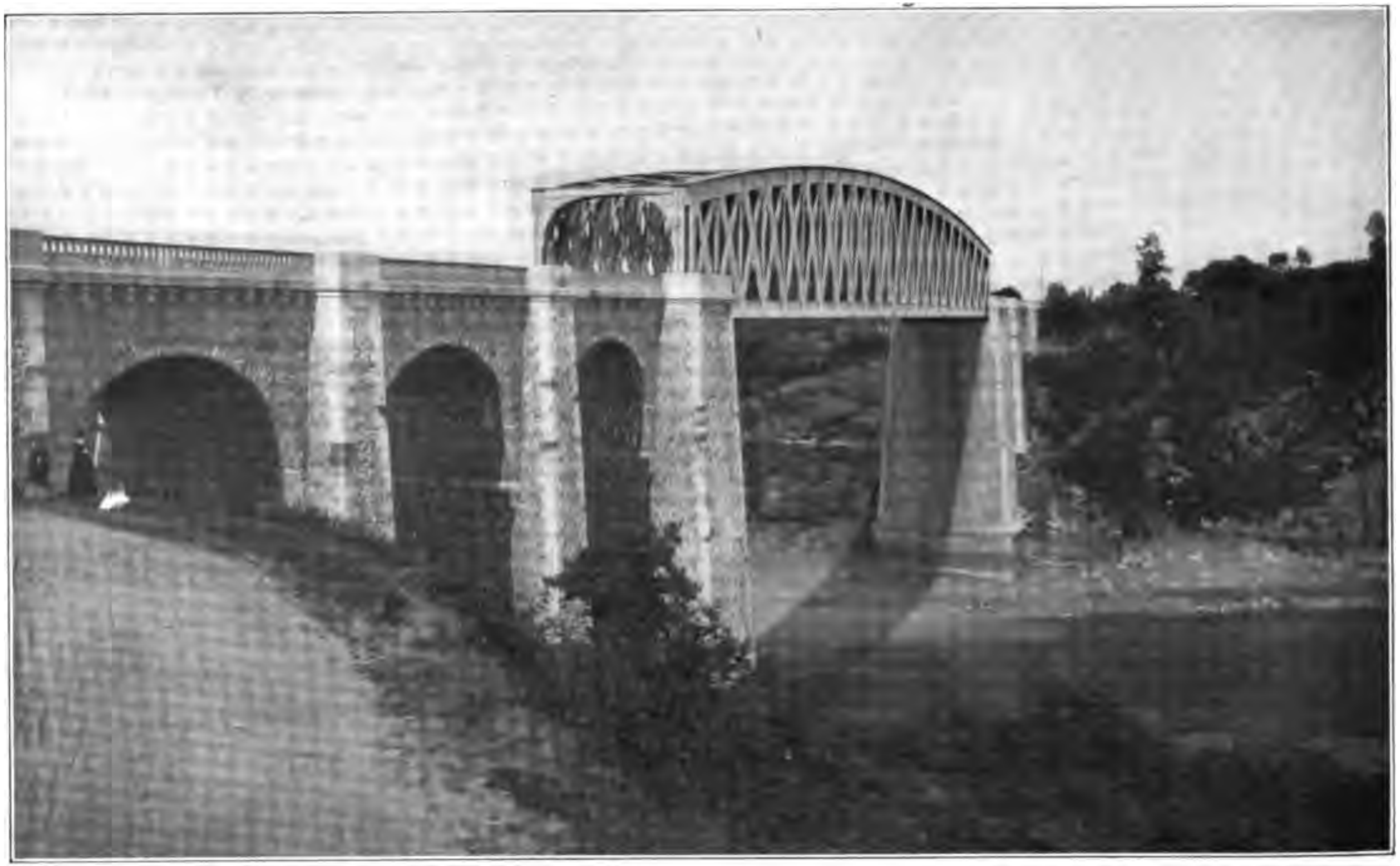
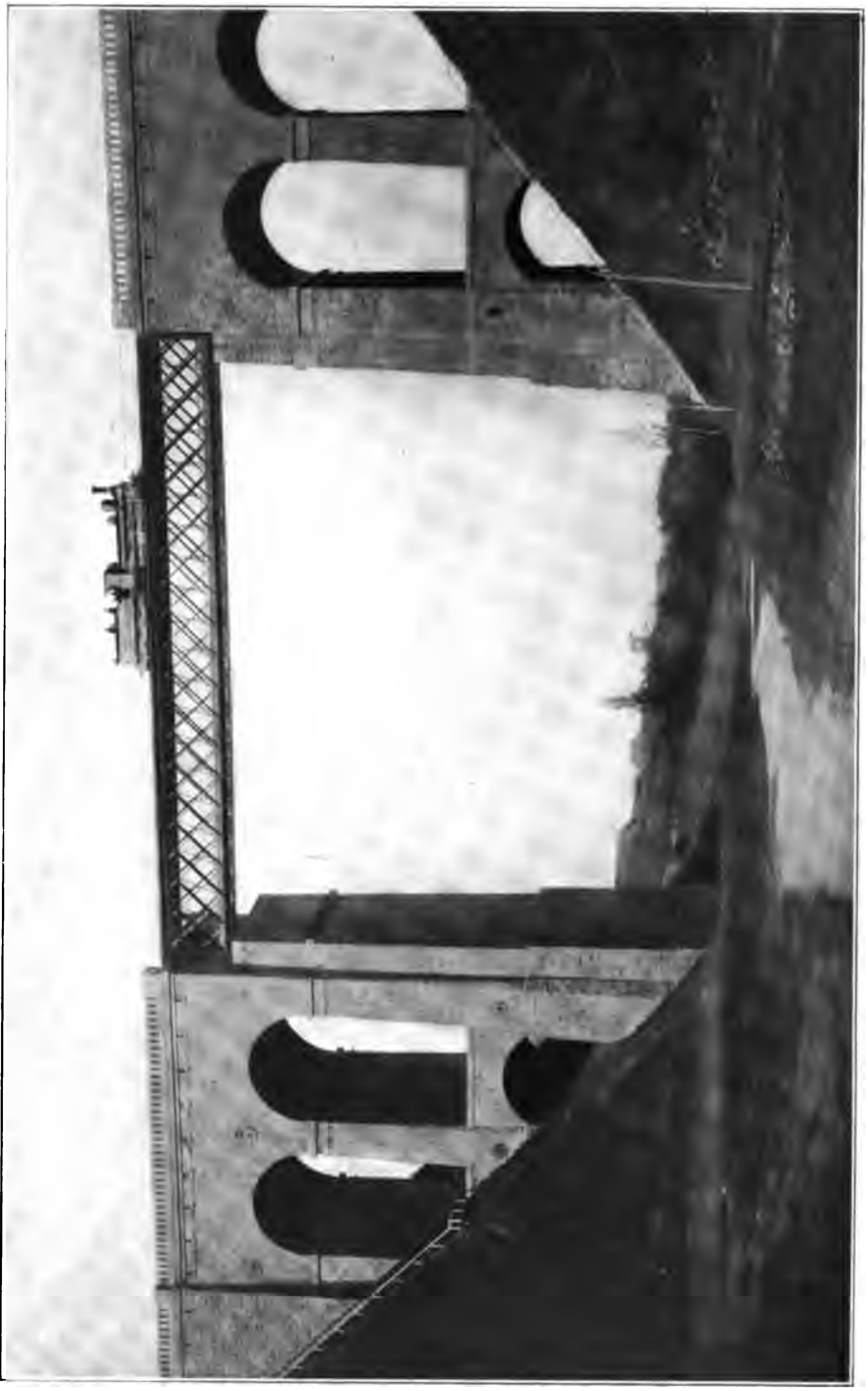


STEPHANIE BRIDGE, VIENNA.



DINAN, FRANCE.



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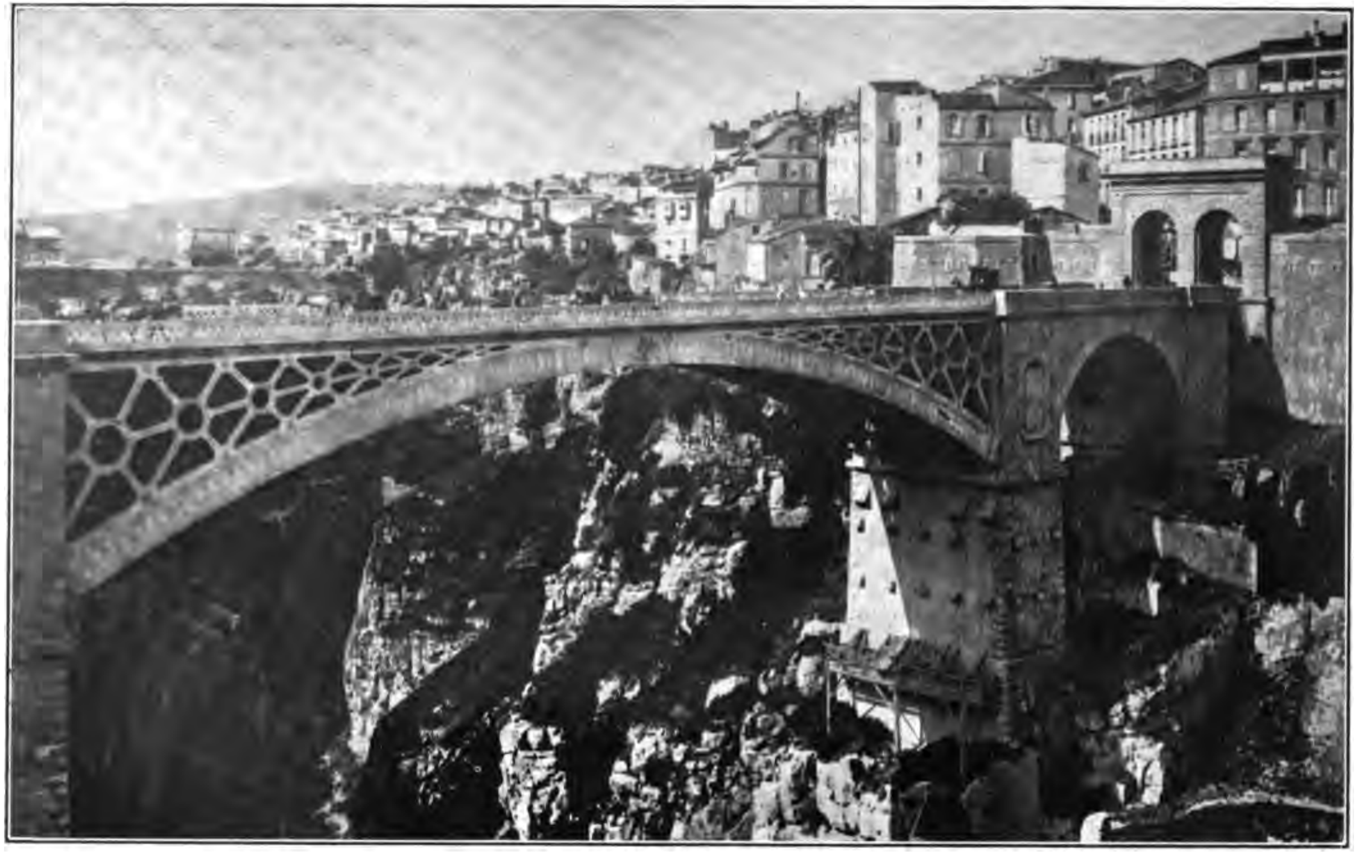
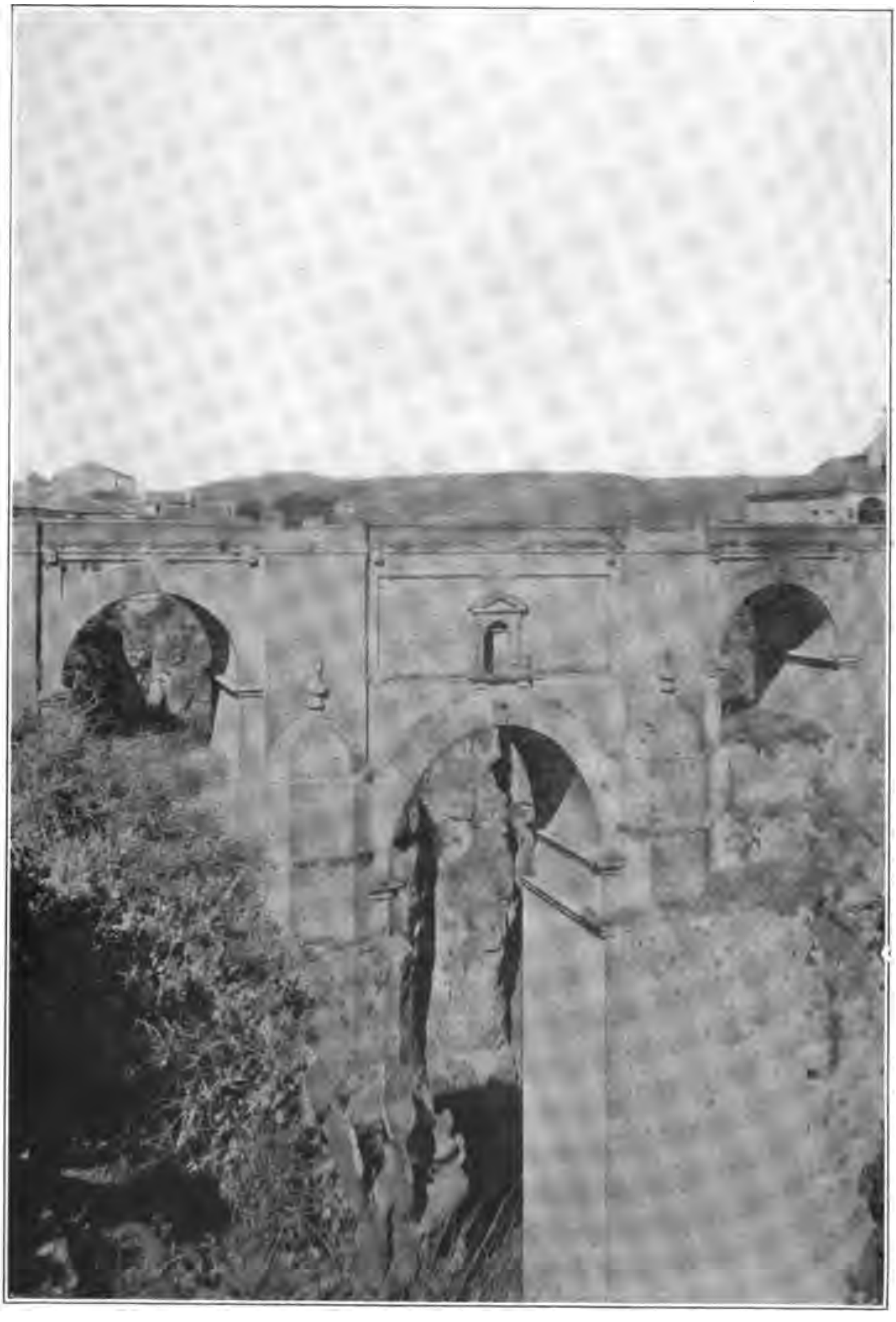


CONSTANTINE, ALGIERS.



RONDA, SPAIN.

BRIDGE APPROACHES.

THE question of harmony is very seldom considered in the designing of the approach spans of any but the most notable of bridges, and some of the most remarkable structures that have been constructed are defective from an architectural standpoint by the failure to provide suitable approaches.

The railway bridge over Niagara, below the falls, is one of the most notable steel arch bridges in the world, being splendidly designed as an engineering and architectural work; and yet the structure as a whole is a failure esthetically by lack of suitable approach spans. The light steel trusses do not present to the eye the solidity necessary for abutments to the great steel arch, and only heavy masonry arches would have given the effect required. There is just as much of a possibility of overdoing the required effect as otherwise, and the approaches to the bridge on the Russian Southwestern State Railways, over the Ingool River, illustrated in this number, are as much too heavy, as those at Niagara are too light. There is, of course, a happy medium, where all is designed in proportion and perfect harmony.

Many suitable and well-proportioned approaches to great bridges are hidden by adjacent city buildings, and their appearance marred by nearby rubbish, or by such things as the landing stages on the levee shown in the illustration of the approaches to the Eads bridge.

The massive approach spans to the East River suspension bridge, at New York, have been closed in across the arch openings and thus turned into warehouse property, presumably excused by the fact that the approaches are hidden, except from a nearby view, by the city buildings close to them.

The problem of designing approach spans for bridges constructed entirely of masonry, is much easier of solution than for structures where the main span or the main portion of the bridge is of metal; but unless the question is decided once for all by the lack of finances, endeavor should be made to make every bridge, of any importance whatever, a success architecturally.

WASHINGTON BRIDGE, NEW YORK CITY.

THE Washington Bridge, as built, is a modification of a design awarded second prize in a competition; the approaches having been designed originally as practically solid wing-wall abutments, but afterwards changed to arches of masonry, much to the enhancing of the beauty of the bridge as a whole.

The east approach consists of one span of 56 feet, with a rise of 28 feet and a keystone 3 feet in depth, and three spans of 59.7 feet each, with a rise of 29.8 feet and a depth of arch-ring at the rise of 4.5 feet and 2 feet at the key. The west approach consists of three spans of the same dimensions as the three equal spans on the east side.

The violation of a fundamental principle in the design of such a bridge by the use of two main spans instead of three or some odd number, is very nearly offset by the appropriateness or harmony of the approaches.

The comparison of the various designs on the inset sheet of "Engineering News" of December 27, 1890, draws forcible attention to the greater beauty of designs having an odd number of main spans, and also to the greater beauty of the bridge with the arched approaches, than the original or contract design. The entire bridge, as constructed, is not excelled anywhere in the world in the beauty and chasteness of its details, and the student and engineer can spend many hours in profitable study of the detail drawings, as published, or on the bridge itself, in gathering ideas of what is best and most harmonious in municipal bridge design.

CHESTNUT STREET, PHILADELPHIA.

THE stone-arch approach spans to the Chestnut Street bridge, in Philadelphia, are well-designed, and suited to the main structure; but the view reproduced is principally of value as illustrating how a work of real merit can be practically ruined by its surroundings, such as the rubbish pile to the left, the old foundation, and the telegraph poles.

The details are very good in the main, but while the arch-rings are very neat, the detail at the springing is bad.

The counterfort over the pier is hardly heavy enough for the size of the spans, but of appropriate finish to harmonize with the abutments of the main spans of the bridge. The paneling of the spandrel-walls is well suited to spans of this size, but the coping and finishing courses should have been made to harmonize with the top of the main abutment; while the balustrade should have been either a solid parapet wall, or of a design as heavy or heavier than is shown over the abutment or on the main spans of the bridge. Attention is also called to the relief afforded to the design by the three pairs of arches in the bridge, as offsetting to some extent the failure to have three main spans.

EADS BRIDGE, ST. LOUIS.

THE Eads bridge across the Mississippi River is one of the notable bridges of the world, and at the time of its construction it was an engineering triumph. The great depth to which the foundations were carried was unprecedented, the length of the steel arch spans was remarkable, and the erection of them a difficult feat.

The successful carrying-out of all these and many other hitherto unsolved problems established James B. Eads as one of the world's greatest engineers; and of all his great undertakings, both before and after the building of the bridge, none will compare with this, his greatest monument.

The approaches to the bridge, as might be expected, are well studied out, and are in perfect harmony with the main spans.

The western approach, shown in the illustration, consists of five semicircular masonry spans of plain, though perfect detail. The piers are of large enough dimensions to allow of the full section of the arch-rings at the springing, while the coping and belt course give the proper finish to the tops of the piers. The arch-stones are dressed and chamfered, making the arch-ring prominent, and the keystones are made larger to properly relieve the arch-ring. The clearstory arches carry the wagonway and add to the general effect of the approaches.

The bad effect of using an even number of spans in an approach can be seen by covering up the span to the left. The entire bridge can safely be taken as one of the best examples of bridge architecture in existence, both in point of general design and of detail.

STEPHANIE BRIDGE, VIENNA.

EUROPEAN bridges, in common with other European engineering works, are more highly finished, as a rule, than those in America. Although of recent years our municipalities have been spending vast sums in bridges which are artistic, as well as examples of good engineering. The Stephaniebruecke, in Vienna, is a typical example of what expense is incurred in making such structures pleasing to the eye, for not only are the bridge and its approaches highly finished and ornamented, but the banks of the stream and all the surroundings are well taken care of.

The bridge having so small a rise in proportion to the span, the great horizontal thrust demands heavy abutments to satisfy appearances, and the approaches are fully suited to the structure and to the location.

The masonry is elegantly detailed, the base and parapet being well-proportioned and designed in harmony with the ornamental work on the arch-span. The parapet railing is also of beautiful design, the pedestals carrying highly ornamental lamp-columns, forming altogether most imposing approaches.

There is seemingly but one exception to be taken to the entire work, and that is the poor design of the steep driveways from the side, where the awkward angle of the wall, the plain wall, and the wooden railings are very objectionable, and well-nigh mar the whole.

DINAN, FRANCE.

THE approaches to the bridge at Dinan, France, are another example of approaches which are too heavy in design to be in harmony with a steel span, although the contrast is not so great as it is in the case of the Russian bridge over the Ingool River.

A main span of masonry or a metal arch would have been more in harmony, however, than the latticed through trusses.

There is nothing whatever worthy of note about the arches, but to have been in harmony with the piers and the entire approaches, the arch-rings should have been of cut stone, or at least made more prominent. The piers are well-designed, but they project too far beyond the face of the arches to look well.

The bracketed coping is of very pleasing detail and the balustrade of appropriate design.

INGOOL RIVER, RUSSIA.

THE masonry abutments and approaches to the bridge over the Ingool River, on the Russian Southwestern State Railways, are of the most massive and imposing character, being similar to many others on the Russian railways. Had the main span of this bridge been a masonry or plate-girder arch, the structure would have been a notable one from every point of view. With the lack of information regarding Russian railway matters, it is impossible to state the object in designing such heavy masonry to carry a light riveted-lattice span of only about 150 feet in length, which looks out of place and very much lighter by contrast than it is in reality.

The length of the abutments above the ground is about 140 feet, and the span of the upper arches about 27.5 feet, they being semicircular.

The work is ornamented very appropriately by the belt course and coping at the top of the spandrel-wall of the lower arch, and by the molded course and coping at the springing of the upper arches.

The brackets and coping at the top are in good proportion, and the plain, though ornamental, balustrade is in entire harmony with the masonry work.

The pains with which everything in connection with the bridge is taken care of are shown by the carefully terraced and sodded embankments, and the neatly rip-rapped banks of the stream.

CONSTANTINE, ALGIERS.

"LE GRAND PONT," at Constantine, Algiers, is a very modern structure and one worthy of a more civilized country. The entire bridge can be studied with great care, as the portal, the approaches, the piers, and the main span are of a most chaste and harmonious design. The piers are very plain, with the exception of the joggled work at the corners, and their neatness is but slightly marred by the projecting stones used for supporting the falsework or centering for the main span.

The approach spans are very simple, but the arch-rings are neatly defined, and the balustrade or parapet wall on the entire approaches, being of solid construction, harmonizes well with the open-work spandrels of the main span and with the central open balustrade.

The portal is a work of architecture in itself, being especially striking in the extreme simplicity of its design, its good proportions, and good details.

RONDA, SPAIN.

THE bridge over a ravine at Ronda, Spain, is illustrated to show to what an extent the matter of approaches can be carried in the wrong direction, and unnecessarily. From all appearances, the ravine should have been spanned by a single arch, of a span equal to at least a greater portion of the distance between the shore abutments of the small or approach spans; and doubtless this could have been done at much less cost, considering the great amount of masonry that was used in building the structure as it exists.

The details of the bridge are very neat, well-proportioned, and harmonious, but the approaches are too heavy for so short a central span, which in itself is massive and out of all proportion to its length; the example is one to be avoided by the engineer designing new bridges of masonry.

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